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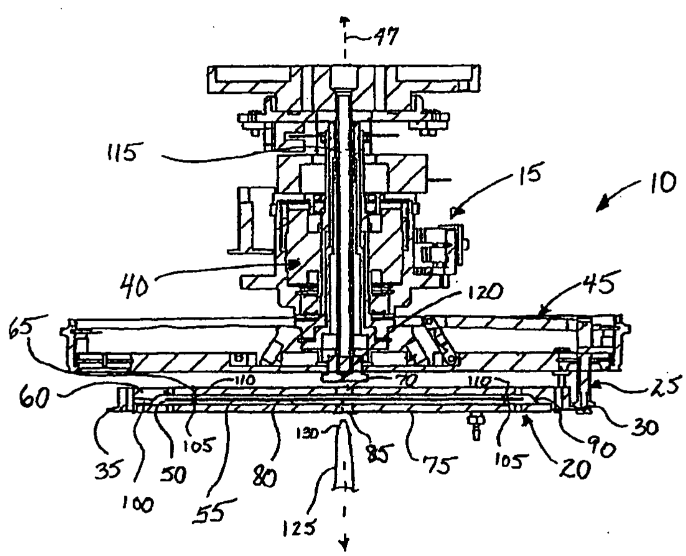

(57) Abstract

An apparatus (10) for processing a workpiece (55) in a micro-environment is set forth. The apparatus includes a rotor motor (40) and a workpiece housing (20). The workpiece housing (20) is connected to be rotated by the rotor motor (40). The workpiece housing (20) further defines a substantially closed processing chamber (50) therein in which one or more processing fluids are distributed across at least one face of the workpiece (55) by centripetal accelerations generated during rotation of the housing (20). Various enhancements to the apparatus and processes using the apparatus are also set forth.

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TITLE OF THE INVENTION

MICRO-ENVIRONMENT REACTOR FOR PROCESSING A MICROELECTRONIC WORKPIECE

BACKGROUND OF THE INVENTION

The industry is constantly seeking to improve the processes used to manufacture microelectronic circuits and components, such as the manufacture of integrated circuits from wafers. The improvements come in various forms but, generally, have one or more objectives as the desired goal. The objectives of many of these improved processes include: 1) decreasing the amount of time required to process a wafer to form the desired integrated circuits; 2) increasing the yield of usable integrated circuits per wafer by, for example, decreasing the likelihood of contamination of the wafer during processing; 3) reducing the number of steps required to turn a wafer into the desired integrated circuits; and 4) reducing the cost of processing the wafers into the desired integrated circuit by, for example, reducing the costs associated with the chemicals required for the processing.

In the processing of wafers, it is often necessary to subject one or more sides of the wafer to a fluid in either liquid, vapor or gaseous form. Such fluids are used to, for example, etch the wafer surface, clean the wafer surface, dry the wafer surface, passivate the wafer surface, deposit films on the wafer surface, etc. Control of the physical parameters of the processing fluids, such as their temperature, molecular composition, dosing, etc., is often quite crucial to the success of the processing operations. As such, the introduction of such fluids to the surface of the wafer occurs in a controlled environment. Typically, such wafer processing occurs

in what has commonly become known as a reactor.

Various reactor constructions and configurations are known and used in the industry. One such reactor is used by Semitool, Inc., and is employed in their Equinox ® brand processing tools. Generally stated, the reactor is comprised of a cup assembly that includes a fixed cup that is constructed from a material that does not chemically react with the processing fluids that are to be used for the particular wafer processing steps. Within the cup, a plurality of nozzles, or other means for introducing fluid into the cup, are provided. The fixed cup has an open top portion. A rotor head assembly that supports the wafer is used to seal the top of the cup to define a processing chamber in which the wafer is housed for processing. In addition to introducing the wafer into the processing chamber, the rotor head assembly may be used to spin the wafer during introduction of the processing fluid onto the surface of the wafer, or after processing to thereby remove the processing fluid.

During processing, the wafer is presented to the rotor head assembly by a robotic device that operates in a substantially clean environment in which a number of processing reactors are present. The robotic device presents the wafer in an exposed state to the rotor head assembly in an orientation in which the side of the wafer that is to be processed is faced up. The rotor head assembly inverts the wafer and engages and seals with the cup for processing. As the wafer is processed, the wafer is oriented so that the side of the wafer being processed is faced down.

The foregoing reactor construction and configuration is quite useful for many of the fluid processing steps employed in the production of an integrated circuit. The present inventor, however, has recognized that demands for future integrated circuit manufacturing processes may ultimately require more control and economic efficiency from the reactor. As such, a

substantially new approach to processing and reactor design has been undertaken which provides greater control of the fluid processes currently used in connection with microelectronic manufacturing, and, further, provides for the implementation and execution of more advanced and improved processes. Additionally, the reactor includes several advantageous mechanical features including those that allow the reactor to be used with robotic wafer transfer equipment, those that allow the reactor to be readily re-configured for different processes, and those that allow the processing chamber of the reactor to be easily removed and serviced.

An apparatus for processing a workpiece in a micro-environment is set forth. Workpiece is defined as an object that at least comprises a substrate, and may include further layers of material or manufactured components, such as one or more rmetallization levels, disposed on the substrate. The apparatus includes a rotor motor and a workpiece housing. The workpiece housing is connected to be rotated by the rotor motor. The workpiece housing further defines a substantially closed processing chamber therein in which one or more processing fluids are distributed across at least one face of the workpiece by centripetal accelerations generated during rotation of the housing. Various enhancements to the apparatus and processes using the apparatus are also set forth.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Fig. 1 is a cross-sectional view of a microelectronic workpiece housing and a rotor assembly constructed in accordance with one embodiment of the invention.

Fig. 2 is an exploded view of a further embodiment of a microelectronic workpiece housing constructed in accordance with the teachings of the present invention

Fig. 3 is a top plan view of the workpiece housing of Fig. 2 when the housing is in an assembled state.

Fig. 4 is a cross-sectional view of the workpiece housing taken along line IV – IV of Fig. 3.

Fig. 5 is a cross-sectional view of the workpiece housing taken along line V – V of Fig. 3.

Fig. 6 is a cross-sectional view of the workpiece housing taken along line VI – VI of Fig. 3.

Figs. 7A and 7B are cross-sectional views showing the workpiece housing in a closed state and connected to a rotary drive assembly.

Figs. 8A and 8B are cross-sectional views showing the workpiece housing in an open state and connected to a rotary drive assembly.

Fig. 9 illustrates one embodiment of an edge configuration that facilitates mutually exclusive processing of the upper and lower wafer surfaces in the workpiece housing.

Fig. 10 illustrates an embodiment of the workpiece housing employed in connection with a self-pumping re-circulation system.

Figs. 11 and 12 are schematic diagrams of exemplary processing tools that employ the present invention.

Fig. 13 illustrates a batch wafer processing tool constructed in accordance with the principles of the present invention.

Fig. 14 illustrates a further embodiment of a reactor including features that render it well-suited for integration with workpiece transfer automation equipment, wherein the reactor is in an open state for loading/unloading a workpiece that is to be processed.

Fig. 15 illustrates the embodiment of the reactor of Fig. 14 wherein the reactor is in a closed processing state.

Fig. 16 illustrates one embodiment of a biasing member that may be used in the reactor of Fig. 14.

Fig. 17 illustrates a system in which the foregoing reactor is used to implement a rinsing/drying process.

Figure 18 is a cut-away, perspective view of the reactor, as seen from a different vantage.

Figure 19 is a cross-sectional view of the reactor, as taken through its central, vertical axis.

Figure 20 is an enlarged detail of certain elements of the reactor, as taken within a circle drawn in Figure 3.

Figures 21 and 22 are further enlarged details of a portion of what is illustrated in Figure 20, as taken at different places around the reactor.

Figure 23 is an enlarged, perspective view of a rotor, as used in the reactor.

Figure 24 is an enlarged, perspective view of a lower chamber wall and four lifting levers, as used in the reactor.

Figures 25 and 26 are further enlarged details of one lifting lever, as seen in two different positions.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 is a cross-sectional view of one embodiment of a reactor, shown generally at 10, constructed in accordance with the teachings of the present invention. The embodiment of the reactor 10 of Fig. 1 is generally comprised of a rotor portion 15 and a microelectronic workpiece housing 20. The rotor portion 15 includes a plurality of support members 25 that extend downwardly from the rotor portion 15 to engage the workpiece housing 20. Each of the support members 25 includes a groove 30 that is dimensioned to engage a radially extending flange 35 that extends about a peripheral region of the workpiece housing 20. Rotor portion 15 further includes a rotor motor assembly 40 that is disposed to rotate a hub portion 45, including the support members 25, about a central axis 47. Workpiece housing 20 is thus secured for co-rotation with hub portion 45 when support members 25 are engaged with flange 35. Other constructions of the rotor portion 15 and the engagement mechanism used for securement with the workpiece housing 20 may also be used.

The workpiece housing 20 of the embodiment of Fig. 1 defines a substantially closed processing chamber 50. Preferably, the substantially closed processing chamber 50 is formed in the general shape of the microelectronic workpiece 55 and closely conforms with the surfaces of the workpiece. The specific construction of Fig. 1 includes an upper chamber member 60 having an interior chamber face 65. The upper chamber member 60 includes a centrally disposed fluid inlet opening 70 in the interior chamber face 65. The specific construction also includes a lower chamber member 75 having an interior chamber face 80. The lower chamber member 75 has a centrally disposed fluid inlet opening 85 in the interior chamber face 80. The upper chamber

member 60 and the lower chamber member 75 engage one another to define the processing chamber 50. The upper chamber member 60 includes sidewalls 90 that project downward from the interior chamber face 65. One or more outlets 100 are disposed at the peripheral regions of the processing chamber 50 through the sidewalls 90 to allow fluid within the chamber 50 to exit therefrom through centripetal acceleration that is generated when the housing 20 is rotated about axis 47.

In the illustrated embodiment, the microelectronic workpiece 55 is a generally circular wafer having upper and lower planar surfaces. As such, the processing chamber 50 is generally circular in plan view and the interior chamber faces 65 and 80 are generally planar and parallel to the upper and lower planar surfaces of the workpiece 55. The spacing between the interior chamber faces 65 and 80 and the upper and lower planar surfaces of the workpiece 55 is generally quite small. Such spacing is preferably minimized to provide substantial control of the physical properties of a processing fluid flowing through the interstitial regions.

The wafer 55 is spaced from the interior chamber face 80 by a plurality of spacing members 105 extending from the interior chamber face 80. Preferably, a further set of spacing members 110 extend from the interior chamber face 65 and are aligned with the spacing members 105 to grip the wafer 55 therebetween.

Fluid inlet openings 70 and 85 provide communication passageways through which one or more processing fluids may enter the chamber 50 for processing the wafer surfaces. In the illustrated embodiment, processing fluids are delivered from above the wafer 55 to inlet 70 through a fluid supply tube 115 having a fluid outlet nozzle 120 disposed proximate inlet 70. Fluid supply tube 115 extends centrally through the rotor portion 15 and is preferably concentric

with the axis of rotation 47. Similarly, processing fluids are delivered from below the wafer 55 to inlet 85 through a fluid supply tube 125. Fluid supply tube 125 terminates at a nozzle 130 disposed proximate inlet 85. Although nozzles 120 and 130 terminate at a position that is spaced from their respective inlets, it will be recognized that tubes 115 and 125 may be extended so that gaps 135 are not present. Rather, nozzles 120 and 130 or tubes 115 and 125 may include rotating seal members that abut and seal with the respective upper and lower chamber members 60 and 75 in the regions of the inlets 70 and 85. In such instances, care should be exercised in the design of the rotating joint so as to minimize any contamination resulting from the wear of any moving component.

During processing, one or more processing fluids are individually or concurrently supplied through fluid supply tubes 115 and 125 and inlets 70 and 85 for contact with the surfaces of the workpiece 55 in the chamber 50. Preferably, the housing 20 is rotated about axis 47 by the rotor portion 15 during processing to generate a continuous flow of any fluid within the chamber 50 across the surfaces of the workpiece 55 through the action of centripetal acceleration. Processing fluid entering the inlet openings 70 and 85 are thus driven across the workpiece surfaces in a direction radially outward from the center of the workpiece 55 to the exterior perimeter of the workpiece 55. At the exterior perimeter of the workpiece 55, any spent processing fluid is directed to exit the chamber 50 through outlets 100 as a result of the centripetal acceleration. Spent processing fluids may be accumulated in a cup reservoir disposed below and/or about the workpiece housing 20. As will be set forth below in an alternative embodiment, the peripheral regions of the workpiece housing 20 may be constructed to effectively separate the processing fluids provided through inlet 70 from the processing fluids

supplied through inlet 85 so that opposite surfaces of wafer 55 are processed using different processing fluids. In such an arrangement, the processing fluids may be separately accumulated at the peripheral regions of the housing 20 for disposal or re-circulation.

In the embodiment of Fig. 1, the workpiece housing 20 may constitute a single wafer pod that may be used to transport the workpiece 55 between various processing stations and/or tools. If transport of the housing 20 between the processing stations and/or tools takes place in a clean room environment, the various openings of the housing 20 need not be sealed. However, if such transport is to take place in an environment in which wafer contaminants are present, sealing of the various housing openings should be effected. For example, inlets 70 and 85 may each be provided with respective polymer diaphragms having slits disposed therethrough. The ends of fluid supply tubes 115 and 125 in such instances may each terminate in a tracor structure that may be used to extend through the slit of the respective diaphragm and introduce the processing fluid into the chamber 50. Such tracor/slitted diaphragm constructions are used in the medical industry in intravenous supply devices. Selection of the polymer material used for the diaphragms should take into consideration the particular processing fluids that will be introduced therethrough. Similar sealing of the outlets 100 may be undertaken in which the tracor structures are inserted into the diaphragms once the housing 20 is in a clean room environment.

Alternatively, the outlets 100 themselves may be constructed to allow fluids from the processing chamber to exit therethrough while inhibiting the ability of fluids to proceed from the exterior of housing 20 into chamber 50. This effect may be achieved, for example, by constructing the openings 100 as nozzles in which the fluid flow opening has a larger diameter at the interior of chamber 50 than the diameter of the opening at the exterior of the housing 20. In a

further construction, a rotational valve member may be used in conjunction with the plurality of outlets 100. The valve member, such as a ring with openings corresponding to the position of outlets 100, would be disposed proximate the opening 100 and would be rotated to seal with the outlets 100 during transport. The valve member would be rotated to a position in which outlets 100 are open during processing. Inert gas, such as nitrogen, can be injected into the chamber 50 through supply tubes 115 and 125 immediately prior to transport of the housing to a subsequent tool or processing station. Various other mechanisms for sealing the outlets 100 and inlets 70 and 85 may also be employed.

Fig. 2 is a perspective view of a further reactor construction wherein the reactor is disposed at a fixed processing station and can open and close to facilitate insertion and extraction of the workpiece. The reactor, shown generally at 200, is comprised of separable upper and lower chamber members, 205 and 210, respectively. As in the prior embodiment, the upper chamber member 205 includes a generally planar chamber face 215 having a centrally disposed inlet 220. Although not shown in the view of Fig. 2, the lower chamber member 210 likewise has a generally planar interior chamber face 225 having a central inlet 230 disposed therethrough. The upper chamber member 205 includes a downwardly extending sidewall 235 that, for example, may be formed from a sealing polymer material or may be formed integrally with other portions of member 205.

The upper and lower chamber members, 205 and 210, are separable from one another to accept a workpiece therebetween. With a workpiece disposed between them, the upper and lower chamber members, 205 and 210, move toward one another to form a chamber in which the workpiece is supported in a position in which it is spaced from the planar interior chamber

faces 215 and 225. In the embodiment of the reactor disclosed in Figs. 2-8B, the workpiece, such as a semiconductor wafer, is clamped in place between a plurality of support members 240 and corresponding spacing members 255 when the upper and lower chamber members are joined to form the chamber (see Fig. 7B). Axial movement of the upper and lower chamber members toward and away from each other is facilitated by a plurality of fasteners 307, the construction of which will be described in further detail below. Preferably, the plurality of fasteners 307 bias the upper and lower chambers to a closed position such as illustrated at Fig. 7A.

In the disclosed embodiment, the plurality of wafer support members 240 extend about a peripheral region of the upper chamber member 205 at positions that are radially exterior of the sidewall 235. The wafer support members 240 are preferably disposed for linear movement along respective axes 245 to allow the support members 240 to clamp the wafer against the spacing members 255 when the upper and lower chamber members are in a closed position (see Fig. 7A), and to allow the support members 240 to release the wafer from such clamping action when the upper and lower chamber members are separated (see Fig. 8A). Each support member 240 includes a support arm 250 that extends radially toward the center of the upper chamber member 205. An end portion of each arm 250 overlies a corresponding spacing member 255 that extends from the interior chamber face 215. Preferably, the spacing members 255 are each in the form of a cone having a vertex terminating proximate the end of the support arm 250. Notches 295 are disposed at peripheral portions of the lower chamber member 210 and engage rounded lower portions 300 of the wafer support members 240. When the lower chamber member 210 is

urged upward to the closed position, notches 295 engage end portions 300 of the support members 240 and drive them upward to secure the wafer 55 between the arms 250 of the supports 240 and the corresponding spacing members 255. This closed state is illustrated in Fig. 5. In the closed position, the notches 295 and corresponding notches 296 of the upper chamber member (see Fig. 2) provide a plurality of outlets at the peripheral regions of the reactor 200. Radial alignment of the arm 250 of each support member 240 is maintained by a set pin 308 that extends through lateral grooves 309 disposed through an upper portion of each support member.

The construction of the fasteners 307 that allow the upper and lower chamber members to be moved toward and away from one another is illustrated in Figs. 2, 6 and 7B. As shown, the lower chamber member 210 includes a plurality of hollow cylinders 270 that are fixed thereto and extend upward through corresponding apertures 275 at the peripheral region of the upper chamber member 205 to form lower portions of each fastener 307. Rods 280 extend into the hollow of the cylinders 270 and are secured to form an upper portion of each fastener 307. Together, the rods 280 and cylinders 270 form the fasteners 307 that allow relative linear movement between the upper and lower chamber members, 205 and 210, along axis 283 between the open and closed position. Two flanges, 285 and 290, are disposed at an upper portion of each rod 280. Flange 285 functions as a stop member that limits the extent of separation between the upper and lower chamber members, 205 and 210, in the open position. Flanges 290 provide a surface against which a biasing member, such as a spring (see Fig. 6) or the like, acts to bias the upper and lower chamber members, 205 and 210, to the closed position.

With reference to Fig. 6, the spring 303 or the like, has a first end that is positioned within a circular groove 305 that extends about each respective fastener 307. A second end of

each spring is disposed to engage flange 290 of the respective fastener 307 in a compressed state thereby causing the spring to generate a force that drives the fastener 307 and the lower chamber member 210 upward into engagement with the upper chamber member 205.

The reactor 200 is designed to be rotated about a central axis during processing of the workpiece. To this end, a centrally disposed shaft 260 extends from an upper portion of the upper chamber member 205. As will be illustrated in further detail below in Figs 7A – 8B, the shaft 260 is connected to engage a rotary drive motor for rotational drive of the reactor 200. The shaft 260 is constructed to have a centrally disposed fluid passageway (see Fig. 4) through which a processing fluid may be provided to inlet 220. Alternatively, the central passageway may function as a conduit for a separate fluid inlet tube or the like.

As illustrated in Figs. 3 and 4, a plurality of optional overflow passageways 312 extend radially from a central portion of the upper chamber member 205. Shaft 260 terminates in a flared end portion 315 having inlet notches 320 that provide fluid communication between the upper portion of processing chamber 310 and the overflow passageways 312. The flared end 315 of the shaft 260 is secured with the upper chamber member 205 with, for example, a mounting plate 325. Mounting plate 325, in turn, is secured to the upper chamber member 205 with a plurality of fasteners 330 (Fig. 5). Overflow passages 312 allow processing fluid to exit the chamber 310 when the flow of fluid to the chamber 310 exceeds the fluid flow from the peripheral outlets of the chamber.

Figs. 7A and 7B are cross-sectional views showing the reactor 200 in a closed state and connected to a rotary drive assembly, shown generally at 400, while Figs. 8A and 8B are similar cross-sectional views showing the reactor 200 in an opened state. As shown, shaft 260 extends

upward into the rotary drive assembly 400. Shaft 260 is provided with the components necessary to cooperate with a stator 405 to form a rotary drive motor assembly 410.

As in the embodiment of Fig. 1, the upper and lower chamber members 205 and 210 join to define the substantially closed processing chamber 310 that, in the preferred embodiment, substantially conforms to the shape of the workpiece 55. Preferably, the wafer 55 is supported within the chamber 310 in a position in which its upper and lower faces are spaced from the interior chamber faces 215 and 225. As described above, such support is facilitated by the support members 240 and the spacing members 255 that clamp the peripheral edges of the wafer 55 therebetween when the reactor 200 is in the closed position of Figs. 7A and 7B.

It is in the closed state of Figs. 7A and 7B that processing of the wafer 55 takes place. With the wafer secured within the processing chamber 310, processing fluid is provided through passageway 415 of shaft 260 and inlet 220 into the interior of chamber 310. Similarly, processing fluid is also provided to the chamber 310 through a processing supply tube 125 that directs fluid flow through inlet 230. As the reactor 200 is rotated by the rotary drive motor assembly 410, any processing fluid supplied through inlets 220 and 230 is driven across the surfaces of the wafer 55 by forces generated through centripetal acceleration. Spent processing fluid exits the processing chamber 310 from the outlets at the peripheral regions of the reactor 200 formed by notches 295 and 296. Such outlets exist since the support members 240 are not constructed to significantly obstruct the resulting fluid flow. Alternatively, or in addition, further outlets may be provided at the peripheral regions.

Once processing has been completed, the reactor 200 is opened to allow access to the wafer, such as shown in Figs. 8A and 8B. After processing, actuator 425 is used to drive an

actuating ring 430 downward into engagement with upper portions of the fasteners 307. Fasteners 307 are driven against the bias of spring 303 causing the lower chamber member 210 to descend and separate from the upper chamber member 205. As the lower chamber member 210 is lowered, the support members 240 follow it under the influence of gravity, or against the influence of a biasing member, while concurrently lowering the wafer 55. In the lower position, the reactor chamber 310 is opened thereby exposing the wafer 55 for removal and/or allowing a new wafer to be inserted into the reactor 200. Such insertion and extraction can take place either manually, or by an automatic robot.

The foregoing arrangement makes the reactor 200 particularly well-suited for automated workpiece loading and unloading by, for example, a robotic transfer mechanism or the like. As evident from a comparison of Figs. 7A and 8A, the spacing between the upper surface of the workpiece and the interior chamber wall of the upper chamber member 205 varies depending on whether the reactor 200 is in an open or closed state. When in the open state, the upper surface of the workpiece is spaced from the interior chamber wall of the upper chamber member 205 by a distance, x1, that provides sufficient clearance for operation of, for example, a workpiece transfer arm of a robotic transfer mechanism. When in the closed processing state, the upper surface of the workpiece is spaced from the interior chamber wall of the upper chamber member 205 by a distance, x2, that is less than the distance, x1. The distance, x2, in the disclosed embodiment may be chosen to correspond to the spacing that is desired during workpiece processing operations.

Fig. 9 illustrates an edge configuration that facilitates separate processing of each side of the wafer 55. As illustrated, a dividing member 500 extends from the sidewall 235 of the

processing chamber 310 to a position immediately proximate the peripheral edge 505 of the wafer 55. The dividing member 500 may take on a variety of shapes, the illustrated tapered shape being merely one configuration. The dividing member 500 preferably extends about the entire circumference of the chamber 310. A first set of one or more outlets 510 is disposed above the dividing member 500 to receive spent processing fluid from the upper surface of the wafer 55. Similarly, a second set of one or more outlets 515 is disposed below the dividing member 500 to receive spent processing fluid from the lower surface of the wafer 55. When the wafer 55 rotates during processing, the fluid through supply 415 is provided to the upper surface of the wafer 55 and spreads across the surface through the action of centripetal acceleration. Similarly, the fluid from supply tube 125 is provided to the lower surface of the wafer 55 and spreads across the surface through the action of centripetal acceleration. Because the edge of the dividing member 500 is so close to the peripheral edge of the wafer 55, processing fluid from the upper surface of the wafer 55 does not proceed below the dividing member 500, and processing fluid from the lower surface of the wafer 55 does not proceed above the dividing member 500. As such, this reactor construction makes it possible to concurrently process both the upper and lower surfaces of the wafer 55 in a mutually exclusive manner using different processing fluids and steps.

Fig. 9 also illustrates one manner in which the processing fluids supplied to the upper and lower wafer surfaces may be collected in a mutually exclusive manner. As shown, a fluid collector 520 is disposed about the exterior periphery of the reactor 200. The fluid collector 520 includes a first collection region 525 having a splatter stop 530 and a fluid trench 535 that is structured to guide fluid flung from the outlets 510 to a first drain 540 where the spent fluid from

the upper wafer surface may be directed to a collection reservoir for disposal or re-circulation. The fluid collector 520 further includes a second collection region 550 having a further splatter stop 555 and a further fluid trench 560 that is structured to guide fluid flung from the outlets 515 to a second drain 565 where the spent fluid from the lower wafer surface may be directed to a collection reservoir for disposal or re-circulation.

Fig. 10 illustrates an embodiment of the reactor 200 having an alternate configuration for supplying processing fluid through the fluid inlet opening 230. As shown, the workpiece housing 20 is disposed in a cup 570. The cup 570 includes sidewalls 575 exterior to the outlets 100 to collect fluid as it exits the chamber 310. An angled bottom surface 580 directs the collected fluid to a sump 585. Fluid supply line 587 is connected to provide an amount of fluid to the sump 585. The sump 585 is also preferably provided with a drain valve 589. An inlet stem 592 defines a channel 595 that includes a first end having an opening 597 that opens to the sump 585 at one end thereof and a second end that opens to the inlet opening 230.

In operation of the embodiment shown in Fig. 10, processing fluid is provided through supply line 587 to the sump 585 while the reactor 200 is spinning. Once the sump 585 is full, the fluid flow to the sump through supply line 587 is eliminated. Centripetal acceleration resulting from the spinning of the reactor 200 provides a pressure differential that drives the fluid through openings 597 and 230, into chamber 310 to contact at least the lower surface of the wafer 55, and exit outlets 100 where the fluid is re-circulated to the sump 585 for further use.

There are numerous advantages to the self-pumping re-circulation system illustrated in Fig. 10. The tight fluid loop minimizes lags in process parameter control thereby making it easier to control such physical parameters as fluid temperature, fluid flow, etc.. Further, there is

no heat loss to plumbing, tank walls, pumps, etc.. Still further, the system does not use a separate pump, thereby eliminating pump failures which are common when pumping hot, aggressive chemistries.

Figs. 11 and 12 illustrate two different types of processing tools, each of which may employ one or more processing stations including the reactor constructions described above. Fig. 11 is a schematic block diagram of a tool, shown generally at 600, including a plurality of processing stations 605 disposed about an arcuate path 606. The processing stations 605 may all perform similar processing operations on the wafer, or may perform different but complementary processing operations. For example, one or more of the processing stations 605 may execute an electrodeposition process of a metal, such as copper, on the wafer, while one or more of the other processing stations perform complementary processes such as, for example, clean/dry processing, pre-wetting processes, photoresist processes, etc.

Wafers that are to be processed are supplied to the tool 600 at an input/output station 607. The wafers may be supplied to the tool 600 in, for example, S.M.I.F. pods, each having a plurality of the wafers disposed therein. Alternatively, the wafers may be presented to the tool 600 in individual workpiece housings, such as at 20 of Fig. 1.

Each of the processing stations 605 may be accessed by a robotic arm 610. The robotic arm 610 transports the workpiece housings, or individual wafers, to and from the input/output station 607. The robotic arm 610 also transports the wafers or housings between the various processing stations 605.

In the embodiment of Fig. 11, the robotic arm 610 rotates about axis 615 to perform the transport operations along path 606. In contrast, the tool shown generally at 620 of the Fig. 12

utilizes one or more robotic arms 625 that travel along a linear path 630 to perform the required transport operations. As in the embodiment of Fig. 10, a plurality of individual processing stations 605 are used, but more processing stations 605 may be provided in a single processing tool in this arrangement.

Fig. 13 illustrates one manner of employing a plurality of workpiece housings 700, such as those described above, in a batch processing apparatus 702. As shown, the workpiece housings 700 are stacked vertically with respect to one another and are attached for rotation by a common rotor motor 704 about a common rotation axis 706. The apparatus 702 further includes a process fluid delivery system 708. The delivery system 708 includes a stationary manifold 710 that accepts processing fluid from a fluid supply (not shown). The stationary manifold 710 has an outlet end connected to the input of a rotating manifold 712. The rotating manifold 712 is secured for co--rotation with the housings 700 and, therefore, is connected to the stationary manifold 710 at a rotating joint 714. A plurality of fluid supply lines 716 extend from the rotating manifold 712 and terminate at respective nozzle portions 718 proximate inlets of the housings 700. Nozzle portions 718 that are disposed between two housings 700 are constructed to provide fluid streams that are directed in both the upward and downward directions. In contrast, the lowermost supply line 716 includes a nozzle portion 718 that directs a fluid stream only in the upward direction. The uppermost portion of the rotating manifold 712 includes an outlet 720 that provides processing fluid to the fluid inlet of the uppermost housing 700.

The batch processing apparatus 702 of Fig. 13 is constructed to concurrently supply the same fluid to both the upper and lower inlets of each housing 700. However, other configurations may also be employed. For example, nozzle portions 718 may include valve

members that selectively open and close depending on whether the fluid is to be supplied through the upper and/or lower inlets of each housing 700. In such instances, it may be desirable to employ an edge configuration, such as the one shown in Fig. 9, in each of the housings 700 to provide isolation of the fluids supplied to the upper and lower surfaces of the wafers 55. Still further, the apparatus 702 may include concentric manifolds for supplying two different fluids concurrently to individual supply lines respectively associated with the upper and lower inlets of the housings 700.

An embodiment of the reactor that is particularly well-suited for integration in an automated processing tool is illustrated in Fig. 14. The reactor, shown generally at 800, includes features that cooperate in a unique manner to allow a robotic arm or the like to insert and extract a workpiece to and from the reactor 800 during loading and unloading operations while also maintaining relatively tight clearances between the workpiece and the interior chamber walls of the reactor during processing.

One of the principal differences between the reactor embodiments described above and the reactor 800 of Fig. 14 lies in the nature of the workpiece support assembly. As shown, reactor 800 includes a workpiece support assembly, shown generally at 805, that is associated with the lower chamber member 210. In accordance with the illustrated embodiment, the workpiece support assembly 805 includes a plurality of workpiece support members 810 that extend through the lower chamber member 210. The workpiece support members 810 are supported at a lower end thereof by a biasing member 815. At the end of the workpiece support member 810 that is distal the biasing member 815, the workpiece support member 810

terminates at a workpiece support surface 820 and a guide structure 825. The guide structure 825 extends from the workpiece support surface 820 and terminates at a frustoconical section 830. The guide structure 825 assists in urging the peripheral edges of the workpiece into proper alignment with the workpiece support surface 820 thereby ensuring proper registration of the workpiece during processing. The guide structure 825 may also serve as a spacer that defines the clearance between the interior chamber wall of the upper chamber member 205 and the upper surface of the workpiece.

The biasing member 815 of the illustrated embodiment serves to bias the workpiece support members 810 in an upward direction when the upper and lower chamber members 205 and 210 are in the illustrated open condition in which the reactor 800 is ready for loading or unloading the workpiece. The biasing member 815 may take on various forms. For example, a single biasing structure may be used that is common to all of the workpiece support members 810. Alternatively, as shown in the disclosed embodiment, individual biasing structures may be respectively associated with individual ones of the workpiece support members 810. The individual biasing structures are in the form of leaf springs 835 but, for example, may alternatively be in the form of coil spring actuators or the like.

As in the embodiment of the reactor described above, the upper and lower chamber members 205 and 210 of reactor 800 are movable with respect to one another between the open condition of Fig. 14 to a closed processing condition as illustrated in Fig. 15. As the chamber members 205 and 210 move toward one another, the frustoconical sections 830 of the workpiece support members 810 engage the interior chamber wall of the upper chamber member 205.

Continued movement between the chamber members 205 and 210 drives the workpiece support members 810 against the leaf springs 835 until the workpiece is clamped between the support surfaces 820 of the workpiece support members 810 and corresponding projections 840 that extend from the interior chamber wall of the upper chamber member 205. While in this closed state, the reactor is ready to process the workpiece.

The reactor 800 of Fig. 14 also includes structures which assists in ensuring proper registration between the upper and a lower chamber members 210 and 205 as they are brought proximate one another to their processing position. In the illustrated embodiment, these structures are in the form of lead-in pins 845 that extend from one of the chamber members to engage corresponding apertures of the other of the chamber members. Here, the lead-in pins 845 extend from the lower chamber member 210 to engage corresponding apertures (not shown) in the upper chamber member 205. The lead-in pins 845 are in the form of upstanding members that each terminate in a respective frustoconical section that functions as a guide surface.

The foregoing arrangement makes the reactor 800 particularly well-suited for automated workpiece loading and unloading by, for example, a robotic transfer mechanism or the like, particularly one in which the workpiece is directly inserted into the reactor without flipping of the workpiece. As evident from a comparison of Figs. 14 and 15, the spacing between the lower surface of the workpiece and the interior chamber wall of the lower chamber member 210 varies depending on whether the reactor 800 is in an open or closed state. When in the open state, the lower surface of the workpiece is spaced from the interior chamber wall of the lower chamber member 210 by a distance, x1, that provides sufficient clearance for operation of, for example, a workpiece transfer arm of a robotic transfer mechanism. When in the closed processing state,

the lower surface of the workpiece is spaced from the interior chamber wall of the lower chamber member 210 by a distance, x2, that is less than the distance, x1. The distance, x2, in the disclosed embodiment corresponds to the spacing that is desired during workpiece processing operations.

One embodiment of the biasing member 815 is illustrated in Fig. 16. As shown, the biasing member 815 is comprised of a plurality of leaf springs 835 that extend radially from a central hub portion 850 to positions in which they contact the underside of respective workpiece support members 810. A further plurality of radial members 855 extend from the hub 850 to positions in which they contact the underside of respective lead-in pins 845. Unlike the leaf springs 835, the further plurality of radial members 855 are not necessarily designed to flex as the upper and lower chamber members 210 and 205 move toward the processing position. The biasing member 825 may be formed from a polymer material or the like which is resistant to the chemistry used in the processing environment. When formed from such a material, the workpiece support members 810 and lead-in pins 845 may be formed integral with their respective leaf springs 835 and radial members 855.

In the illustrated embodiment, the central hub portion 850 includes a central aperture 900 that accommodates a securement 905 which connects the biasing member 815 to the underside of the lower chamber member 210. With reference to Figs. 14 and 15, the securement 905 can be formed to provide the processing fluid inlet through the lower chamber member 210. When the securement 905 is formed in this manner, the reactor 800 is provided with a quick and easy manner of providing different inlet configurations for different processes.

On occasion, it may be desirable to remove the reactor 800 from head portion 860. For

example, the reactor 800 may be removed for service or for replacement with a reactor that is designed for executing other processes, or processing other workpiece types.

To this end, the reactor 800 and the head portion 860 are engaged at a connection hub assembly 865 which allows the reactor 800 to be easily connected to and disconnected from the head portion 860. In embodiment illustrated in Fig. 15, the connection hub assembly 865 is comprised of a head connection hub 870 that is fixed to the processing head portion 860, and a reactor connection hub 875 that is fixed to the reactor 800. The connection hubs 870 and 875 are secured to one another during normal operation by, for example, a threaded joint 880. A set screw 885 extends through the head connection hub 870 and may be rotated to engage a surface of or corresponding aperture in the reactor connection hub 875 to thereby prevents the connection hubs 870 and 875 from unscrewing.

When removal of the reactor 800 is desired, the reactor is rotated to align set screw 885 with a corresponding channel sleeve 890 that is fixed to the head portion 860. The channel sleeve 890 is constructed to allow a user to extend a tool therethrough to engage the set screw 885. The set screw is then turned to raise it until it engages and secures with a screw head block 895. Once secured in this manner, the head connection hub 870 is rotationally locked with the head portion 860 thereby allowing the reactor 800 and corresponding reactor connection hub 875 to be unscrewed from the head connection hub 870 to remove the reactor.

In accordance with a still further feature of the reactor 800, a stiffening member 910 formed, for example, from aluminum is secured with the upper chamber member 205. By increasing the stiffness of the upper and/or lower chamber members, higher rotating speeds may be used and, further, the flatness of the interior chamber walls during processing may be

increased.

Numerous substantial benefits flow from the use of the disclosed reactor configurations. Many of these benefits arise directly from the reduced fluid flow areas in the reactor chambers. Generally, there is a more efficient use of the processing fluids since very little of the fluids are wasted. Further, it is often easier to control the physical parameters of the fluid flow, such as temperature, mass flow, etc., using the reduced fluid flow areas of the reactor chambers. This gives rise to more consistent results and makes those results repeatable.

The foregoing constructions also give rise to the ability to perform sequential processing of a single wafer using two or more processing fluids sequentially provided through a single inlet of the reaction chamber. Still further, the ability to concurrently provide different fluids to the upper and lower surfaces of the wafer opens the opportunity to implement novel processing operations. For example, a processing fluid, such as HF liquid, may be supplied to a lower fluid inlet of the reaction chamber for processing the lower wafer surface while an inert fluid, such as nitrogen gas, may be provided to the upper fluid inlet. As such, the HF liquid is allowed to react with the lower surface of the wafer while the upper surface of the wafer is effectively isolated from HF reactions. Numerous other novel processes may also be implemented.

The present inventor has recognized that demands for integrated circuit rinsing/drying processes may ultimately require more control and economic efficiency from the rinser/dryer. As such, a substantially new approach to rinsing and drying of the semiconductor wafer has been undertaken which provides greater control of the physical properties of the rinsing and drying fluids. Further, wafers may be rinsed and dried on an individual basis more quickly

when compared to the drying of an individual wafer using any of the foregoing processes.

Fig. 17 illustrates one manner of controlling the provision of rinsing/drying fluids that are supplied to the rinser/dryer of any of the foregoing embodiments. As illustrated, the fluid supply system, shown generally at 1800, includes a nitrogen gas supply 1805, an IPA supply 1810, an IPA vaporizer 1815, a DI water supply 1820, optional heating elements 1825, optional flowmeters 1830, optional flow regulators/temperature sensors 1835, and valve mechanism 1840. All of the various components of the system 1800 may be under the control of a controller unit 845 having the appropriate software programming.

In operation of the rinser/dryer, the valve mechanism 1840 is connected to supply DI water from supply 1820 to both the upper and lower inlets of the rinser/dryer chamber. As the water is supplied to the chamber, the wafer is spun at, for example, a rate of 200 RPM. This causes the water to flow across each surface of the wafer under the action of centripetal acceleration. Once a sufficient amount of water has been supplied to the chamber to rinse the wafer surfaces, valve mechanism 1840 is operated to provide a drying fluid, preferably comprised of nitrogen and IPA vapor, to both the upper and lower inlets of the rinser/dryer chamber. Valve mechanism 1840 is preferably operated so that the front of the drying fluid immediately follows the trailing end of the DI water. As the drying fluid enters the chamber, centripetal acceleration resulting from the spinning of the wafer drives the drying fluid across the wafer surface and follows a meniscus across the wafer surface formed by the DI water. The IPA vapor assists in providing a drying of the surface of the wafer at the edge of the meniscus. Drying of the wafer may be further enhanced by heating the DI water and/or the

nitrogen/IPA vapor using heating elements 1825. The particular temperature at which these fluids are supplied may be controlled by the controller 1845. Similarly, flow regulators 1835 and flowmeters 1830 may be used by controller 1845 to regulate the flow of the DI water and/or the nitrogen/IPA vapor to the rinser/dryer chamber.

With some modifications, the foregoing reactor designs may be adapted to execute several unique processes in which contact between the microelectronic workpiece and one or more processing fluids is controlled and confined to selected areas of the workpiec. One embodiment of such a reactor design is shown in Figures 18-22.

With reference to Figures 18-22, there is shown a reactor 2100 for processing a microelectronic workpiece, such as a silicon wafer 10 having an upper side 12, a lower side 14, and an outer, circular perimeter 16, in a micro-environment. For certain applications, the upper side 12 is the front side, which may be otherwise called the device side, and the lower side 14 is the back side, which may be otherwise called the non-device side. However, for other applications, the silicon wafer 10 is inverted.

Generally, except as disclosed herein, the reactor 2100 is similar to the reactors illustrated and described above. However, as illustrated in the drawings and described herein, the reactor 2100 is improved to be more versatile in executing selected microelectronic fabrication processes.

The reactor 2100 has an upper chamber member that includes an upper chamber wall 2120 and a lower chamber member that includes a lower chamber wall 2140. These walls 2120, 2140, are arranged to open so as to permit a wafer 10 to be loaded into the reactor 100 for

processing, by a loading and unloading mechanism (not shown) that, for example, may be in the form of a robot having an end effector. These walls 2120, 2140, are arranged to close so as to define a capsule 2160 supporting a wafer 10 in a processing position, between these walls 2120, 2140.

The reactor 2100, which defines a rotation axis A, has a head 2200 containing a rotor 2210, which mounts the upper chamber wall 2120, and mounting a motor 2220 for rotating the rotor 2210 and the upper and lower chamber walls 2120, 2140, when closed, around the axis A, conjointly with a wafer 10 supported in the processing position. The motor 2220 is arranged to drive a sleeve 2222, which is supported radially in the head 2200, by rolling-element bearings 2224. The head 2200 is arranged to be raised for opening these walls 2120, 2140, and to be lowered for closing these walls 2120, 2140.

The upper chamber wall 2120 has an inlet 2122 for processing fluids, which may be liquid, vaporous, or gaseous, and the lower chamber wall 2140 has an inlet 2142 for such fluids, which for a given application may be similar fluids or different fluids. The head 2200 mounts an upper nozzle 2210, which extends axially through the sleeve 2222 so as not to interfere with the rotation of the sleeve 2222. The upper nozzle 2210 directs streams of processing fluids downwardly through the inlet 2122 of the upper chamber wall 2120.

The upper chamber wall 2120 includes an array of similar outlets 2124, which are spaced similarly at uniform angular spacings around the vertical axis A. In the disclosed embodiment, thirty-six such outlets 2124 are employed. Each

outlet 2124 is spaced outwardly from the vertical axis A by a comparatively larger radial distance and is spaced inwardly from the outer perimeter 16 of a wafer 10 supported in the processing position by a comparatively smaller radial distance, such as a distance of approximately 1.5 millimeters.

When the upper and lower chamber walls 2120, 2140, are closed, they define a micro-environment reactor 2160 the having an upper processing chamber 2126 that is defined by the upper chamber wall 2120 and by a first generally planar surface of the supported wafer 10, and a lower processing chamber 2146 that is defined by the lower chamber wall 2140 and a second generally planar surface of the supported wafer opposite the first side. The upper and lower processing chambers 2126, 2146, are in fluid communication with each other in an annular region 2130 beyond the outer perimeter 16 of the supported wafer 10 and are sealed by an annular, compressible seal (*e.g.* O-ring) 2132 bounding a lower portion 2134 of the annular region 2130. The seal 2132 allows processing fluids entering the lower inlet 2142 to remain under sufficient pressure to flow toward the outlets 2134.

As compared to reactors of the type disclosed in the previously described embodiments, the reactor 2100 is particularly suitable for executing a range of unique microfabrication processes. For example, reactor 2100 is particularly suited to execute a process that requires complete contact of a processing fluid at a first side of a workpiece and at only a peripheral margin portion of the second side thereof. Such processes may be realized because processing fluids entering the inlet

2142 of the lower chamber wall 2140 can act on the lower side 14 of a supported wafer 10, on the outer periphery 16 of the supported wafer 10, and on an outer margin 18 of the upper side 12 of the supported wafer 10 before reaching the outlets 2124, and because processing fluids entering the inlet 2122 of the upper chamber wall 2120 can act on the upper side 12 of the supported wafer 10, except for the outer margin 18 of the upper side 12, before reaching the outlets 2124.

As a significant example of one such process, the reactor 2100 can be used with control of the respective pressures of processing fluids entering the respective inlets 2122, 2142, to carry out a process in which a processing fluid is allowed to contact a first side of the workpiece, the peripheral edge of the workpiece, and a peripheral region of the opposite side of the workpiece. Such fluid flow/contact can also be viewed as a manner of excluding a processing fluid that is applied to the opposite side from a peripheral region of that side. In accordance with one embodiment of such a process, a thin film of material is etched from the first side, peripheral edge of the workpiece, and peripheral region of the opposite side of the workpiece.

In a more specific embodiment of such a process, the process may employed in a metallization process that is used to form a microelectronic component and/or interconnect structures on a semiconductor wafer or the like. To this end, a thin film, such as the seed layer, is applied over a barrier layer on the front side and over at least a portion of the outer perimeter. After one or more intervening steps, such as electroplating of a copper layer or the like thereover, an

etchant capable of etching the electroplating material, thin film material, and/or the barrier layer material is caused to flow selectively over only an outer margin of the first side while being concurrently prevented from flowing over other radial interior portions of the first side. Thus, one or more of the layers are removed from the outer margin of the first side while the layers remain intact at the portions of the first side that are disposed interior of the outer margin. If the etchant is driven over the opposite side and over the outer perimeter, as well as over the outer margin of the first side, the one or more layers are also removed from the outer perimeter of the wafer and, further, any contaminant that the etchant is capable of removing is stripped from the back side.

Based on the description of the foregoing process, it will be recognized that other layers and/or materials may be selectively etched, cleaned, deposited, protected, etc., based on selective contact of a processing fluid with the outer margin and/or opposing side of the workpiece. For example, oxide may be removed from the opposite side and outer margin of the first side of a workpiece through selective contact with an oxide etchant, such as hydrofluoric acid. Similarly, the oxide etchant may be controlled in the reactor so that it contacts all of the front side of the workpiece except for the outer margin thereby leaving the oxide at the outer margin intact. It will also be recognized that removal of the outlets 2124 allows the reactor 2100 to be used for processes in which selective outer margin inclusion or exclusion is unnecessary or otherwise undesirable.

As illustrated in Figures 23-26, additional structures may be incorporated with any of the foregoing reactors dependent on the particular process(es) the reactor is designed to implement and the automation, if any, that will be used along with it. In accordance with one such structural addition, the lower chamber wall 140 has an upper surface 2144 shaped so as to define an annular sump 2146 around the inlet 2142. The sump 2146 is used to collect liquid byproducts and/or residual processing fluids supplied through the inlet 2142. If a liquid, for example, strikes and drops from wafer 10, it is conducted toward the outlet 2124 under the influence of centripetal acceleration as the reactor 100 is rotated.

Another structural addition illustrated in connection with the reactor 2100 relates to the lower nozzle design. As illustrated, the lower nozzle 2260, which is provided beneath the inlet 2142 of the lower chamber wall 2140, includes two or more ports 2262 (two shown) for directing two or more streams of processing fluids upwardly through the inlet 2142. The ports 2262 are oriented so as to cause the directed streams to converge approximately where the directed streams reach the lower surface of the wafer 10. The reactor 2100 also includes a purging nozzle 2280, which is disposed at a side of the lower nozzle 2260, for directing a stream of purging gas, such as nitrogen, across the lower nozzle 2260.

Still further, the reactor 2100 may have a base 2300, which mounts the lower nozzle 2260 and the purging nozzle 2280 and which defines a coaxial, annular plenum 2320. The plenum 2320 has plural (*e.g.* four) drains 2322 (one shown) each of which is equipped with a pneumatically actuated, poppet valve

2340 for opening and closing the drain 2322. These drains 2322 provide separate paths for conducting processing liquids of different types to appropriate systems (not shown) for storage, disposal, or recirculation.

An annular skirt 2360 extends around and downwardly from the upper chamber wall 2120, above the plenum 2320, so as to be conjointly rotatable with the upper chamber wall 2140. Each outlet 2124 is oriented so as to direct processing fluids exiting such outlet 2124 through fluid passages 2364 against an inner surface 2362 of the annular skirt 2360. The inner surface 2362 is flared outwardly and downwardly, as shown, so as to cause processing fluids reaching the inner surface 2362 to flow outwardly and downwardly toward the plenum 2320, under the influence of centripetal acceleration when the reactor is rotated. Thus, processing fluids tend to be swept through the plenum 2320, toward the drains 2322.

The rotor 2210 has a ribbed surface 2215 facing and closely spaced from a smooth surface 2202 of the rotor 2210, in an annular region 204 communicating with the plenum 2320. When the rotor 2210 rotates, the ribbed surface 2215 tends to cause air in the annular region 2204 to swirl, so as to help to sweep processing fluids through the plenum 2320, toward the drains 2322.

The upper chamber wall 2120 has spacers 2128 that project downwardly to prevent the lifting of a supported wafer 10 from the processing position and from touching the upper chamber wall 2120. The lower chamber wall 2140 has spacers 2148 that project upwardly for spacing a supported wafer 10 above the lower

chamber wall 140 by a given distance, and posts 2150 projecting upwardly beyond the outer perimeter 16 of a supported wafer 10 for preventing the supported wafer 10 from shifting off center from the vertical axis A.

The lower chamber wall 2140 may mount a lifting mechanism 2400 for lifting a wafer 10 supported in the processing position to an elevated position. The lifting mechanism lifts the wafer 10 to the elevated position when the head 2200 is raised above the base 2300 so as to open the upper and lower chamber walls 2120, 2140. Lifting a supported wafer 10 to the elevated position facilitates its being unloaded by a loading and unloading mechanism (not shown) such as a robotic arm having an end effector.

The lifting mechanism 2400 includes an array of lifting levers 2420. Each lifting lever 2420 is mounted pivotably to the lower chamber wall 2140 via a pivot pin 2422 extending from such lifting lever 2420 into a socket 2424 in the lower chamber wall 2140, so as to be pivotable between an operative position and an inoperative position. Each pivoting lever 2420 is arranged to be engaged by the upper chamber wall 2120 when the upper and lower chamber walls 2120, 2140, are closed, whereby such pivoting lever 2420 is pivoted into the inoperative position. Each lifting lever 2420 is biased, as described below, so as to pivot into the operative position when not engaged by the upper chamber wall 2120.

Thus, each lifting lever 420 is adapted to pivot from the operative position into the inoperative position as the upper and lower chamber walls 2120, 2140, are closed, and is adapted to pivot from the inoperative position into the operative

position as the upper and lower chamber walls 2120, 2140, are opened. Each lifting lever 2420 mounts a pin 2424, which extends beneath a wafer 10 supported in the processing position and lifts the supported wafer to the elevated position, when such lifting lever 2420 is pivoted from the inoperative position into the operative position.

The lifting levers 2420 may be biased by an elastic member 2440 (*e.g.* O-ring) surrounding the lower chamber wall 2140 and engaging the lifting levers 2420, via a hook 2426 depending from each lifting lever 2420. On each lifting lever 2420, the pin 2422 defines an axis, relative to which the pin 2424 and the hook 2426 are opposed diametrically to the each other. The elastic member 2440 is maintained under comparatively higher tension when the upper and lower chamber walls 2120, 2140, are closed, and under comparatively lower tension when the upper and lower chamber walls 2120, 2140, are opened.

The upper and lower chamber walls 2120, 2140, may also be releasably clamped to each other when in the closed state by a latching mechanism 2500. In accordance with one embodiment, the latching mechanism, the latching mechanism includes a latching ring 2520 that is retained by the lower chamber wall 2140 and that is adapted to engage a complementary shaped recess 2540 disposed in the upper chamber wall 2120. The latching ring 2520 is made from a resilient spring material (*e.g.* polyvinylidine fluorid) with an array of inwardly stepped portions 2530. Thus stepped portions 2530 enable the latching ring 2520 to deform from an undeformed condition in which the latching ring 2520 has a first diameter into a

deformed condition in which the latching ring 2520 has a comparatively smaller diameter. Such deformation occurs when the stepped portions 2530 are subject to radial inward directed forces. Upon removal of the forces, the latching ring 2520 returns to the undeformed.

The latching mechanism 2500 further includes an array of latching cams 2540, each associated with a respective one of the stepped portions 2530. Each latching cam 2540 is adapted to apply radial forces to the respective stepped portions 2530.

The latching mechanism 2500 further includes an actuating ring 2560, which is adapted to actuating the latching cams 540 as the actuating ring 2560 is raised and lowered within a predetermined limited range of movement.. In the illustrated embodiment, the actuating ring 2560 is adapted, when raised, to actuate the latching cams 2540, and, when lowered, to deactuate the latching cams. The latching mechanism 2500 further includes an array of pneumatic devices 2580 (e.g. three such devices) which are adapted to raise and lower the actuating ring 2560. When the actuating ring 2560 is raised, the upper and lower chamber walls 2120, 2140, are released from each other so that the head 2200 can be raised from the base 2300 for opening the upper and lower chamber walls 2120, 2140, or lowered onto the base 2300 for closing the upper and lower chamber walls 2120, 2140.

The actuating ring 2560 mounts upwardly projecting pins 2562 (one shown) that project into respective ones of multiple apertures 2564 in an aligning ring 2570 when the actuating ring 2560 is raised. The aligning ring 2570 is mounted to rotate

conjointly with the lower chamber wall 2140. The pins 2562 are withdrawn from the apertures 2564 and clear the aligning ring 2570 when the actuating ring 2560 is lowered. When projecting into the respective apertures 2564, the pins 2562 align a wafer 10 that had been supported in the processing position so as to facilitate unloading the wafer 10 via a robotic system, as mentioned above.

The present invention has been illustrated with respect to a wafer. However, it will be recognized that the present invention has a wider range of applicability. By way of example, the present invention is applicable in the processing of disks and heads, flat panel displays, microelectronic masks, and other devices requiring effective and controlled wet processing.

Numerous modifications may be made to the foregoing system without departing from the basic teachings thereof. Although the present invention has been described in substantial detail with reference to one or more specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the scope and spirit of the invention as set forth in the appended claims.

CLAIMS

1. An apparatus for processing a workpiece in a micro-environment, the apparatus comprising:

a rotor motor;

a workpiece housing connected for rotation by the rotor motor, the workpiece housing including therein a substantially closed processing chamber in which one or more processing fluids are distributed across at least one face of the workpiece by centripetal acceleration generated during rotation of the housing.

2. An apparatus as claimed in claim 1 and further comprising a fluid supply system connected to sequentially supply a rinsing fluid followed by a drying fluid to the processing chamber.

3. An apparatus as claimed in claim 1 wherein the workpiece housing further comprises:

at least one fluid inlet opening to the processing chamber and aligned with an axis of rotation of the housing; and

at least one fluid outlet extending from the processing chamber, the at least one fluid outlet positioned to allow escape of fluid from the processing chamber through action of centripetal acceleration generated during rotation of the workpiece housing about the axis of rotation.

4. An apparatus as claimed in claim 3 wherein the at least one fluid inlet opening is disposed through an upper portion of the processing chamber to thereby facilitate distribution of a fluid across an upper face of the workpiece through the action of centripetal acceleration.

5. An apparatus as claimed in claim 3 wherein the at least one fluid inlet opening is disposed through a lower portion of the processing chamber to thereby facilitate distribution of a fluid across a lower face of the workpiece through the action of centripetal acceleration.

6. An apparatus as claimed in claim 1 wherein the workpiece housing is a transportable pod.

7. An apparatus as claimed in claim 1 wherein the workpiece housing comprises upper and lower chamber members connected to one another to define the substantially closed processing chamber.

8. An apparatus as claimed in claim 1 wherein the workpiece housing comprises:

an upper chamber member having an interior chamber face, the upper chamber member including a centrally disposed fluid inlet opening in the interior chamber face thereof;

a lower chamber member having an interior chamber face, the lower chamber member including a centrally disposed fluid inlet opening in the interior chamber face thereof;

the upper chamber member and the lower chamber member being joined to one another to form the substantially closed processing chamber, the processing chamber generally conforming to the shape of the workpiece, the substantially closed processing chamber having at least one fluid outlet disposed at a peripheral region thereof to facilitate escape of fluid from the processing chamber through action of centripetal acceleration.

9. An apparatus as claimed in claim 8 wherein the workpiece housing further comprises:

at least one workpiece support adapted to support a workpiece in the substantially closed processing chamber in a position spaced from and generally parallel to the interior chamber face of the upper and lower chamber members, the workpiece support positioning the workpiece within the processing chamber to allow distribution of a fluid supplied through the inlet opening of the upper chamber member across at least an upper face of the workpiece through the action of centripetal acceleration, and to allow distribution of a fluid supplied through the inlet opening of the lower chamber member across at least a lower face of the workpiece through the action of centripetal acceleration.

10. An apparatus as claimed in claim 1 wherein the workpiece housing comprises:

an upper chamber inlet for supplying a first fluid flow into an upper region of the processing chamber for distribution of the first fluid flow across at least an upper surface of the workpiece through the action of centripetal acceleration; and

a lower chamber inlet for supplying a second fluid flow into a lower region of the processing chamber for distribution of the second fluid flow across at least a lower surface of the workpiece through the action of centripetal acceleration.

11. An apparatus as claimed in claim 10 and further comprising a dividing member disposed in the processing chamber about a peripheral edge of the workpiece at a position in which the dividing structure separates distribution flow of the first and second fluid flows, whereby the first fluid flow is principally limited to contacting the upper face of the workpiece and the second fluid flow is principally limited to contacting the lower face of the workpiece.

12. An apparatus for processing a workpiece in a micro-environment, the apparatus comprising:

a plurality of walls defining a substantially closed processing chamber, the substantially closed processing chamber having at least one fluid outlet disposed at a peripheral region thereof, and at least one fluid inlet disposed to allow a fluid to enter the processing chamber at a non-peripheral region;

at least one workpiece support adapted to support a workpiece in the substantially closed processing chamber in a position to allow distribution of a fluid supplied through the fluid inlet across at least one face of the workpiece through action of centripetal acceleration, the at least one fluid outlet being positioned to allow escape of fluid from the processing chamber through action of centripetal acceleration.

13. An apparatus as claimed in claim 12 and further comprising a fluid supply system connected to sequentially supply a rinsing fluid followed by a drying fluid to the at fluid inlet.

14. An apparatus as claimed in claim 12 wherein the at least one fluid inlet is disposed at a central portion of the processing chamber.

15. An apparatus as claimed in claim 12 wherein the at least one fluid inlet is disposed at a central upper portion of the processing chamber to supply a flow of fluid proximate an upper surface of the workpiece.

16. An apparatus as claimed in claim 12 wherein the at least one fluid inlet is disposed at a central lower portion of the processing chamber to supply a flow of fluid proximate a lower surface of the workpiece.

17. An apparatus as claimed in claim 12 wherein the workpiece housing comprises:

an upper chamber inlet for supplying a first fluid flow into an upper region of the processing chamber for distribution of the first fluid flow across at least an upper surface of the workpiece through the action on centripetal acceleration; and

a lower chamber inlet for supplying a second fluid flow into a lower region of the processing chamber for distribution of the second fluid flow across at least a lower surface of the workpiece through the action of centripetal acceleration.

18. An apparatus as claimed in claim 17 and further comprising a dividing structure disposed in the processing chamber about a peripheral edge of the workpiece at a position in which the dividing structure separates distribution flow of the first and second fluid flows, whereby the first fluid flow is principally limited to contacting the upper face of the workpiece and

the second fluid flow is principally limited to contacting the lower face of the workpiece.

19. An apparatus as claimed in claim 12 wherein the substantially closed processing chamber generally conforms to the shape of the workpiece.

20. An apparatus as claimed in claim 19 wherein the workpiece is a generally circular semiconductor wafer, the plurality of walls comprising:

a generally planar upper interior chamber face;

a generally planar lower interior chamber face;

the upper and lower interior chamber faces being disposed so as to be generally parallel with upper and lower planar surfaces of the semiconductor wafer, respectively.

21. An apparatus for processing a workpiece in a micro-environment, the apparatus comprising:

an upper chamber member having a fluid inlet opening ;

a lower chamber member having a fluid inlet opening;

the upper chamber member and the lower chamber member being joined to one another to form a substantially closed processing chamber generally conforming to the shape of the workpiece, the substantially

closed processing chamber having at least one fluid outlet disposed at a peripheral region thereof;

at least one workpiece support adapted to support a workpiece in the substantially closed processing chamber in a position to allow distribution of a fluid supplied through the inlet opening of the upper chamber member across at least an upper face of the workpiece through the action of centripetal acceleration, and to allow distribution of a fluid supplied through the inlet opening of the lower chamber member across at least a lower face of the workpiece through the action of centripetal acceleration, the at least one fluid outlet being positioned to allow escape of fluid from the processing chamber through action of centripetal acceleration.

22. An apparatus as claimed in claim 21 and further comprising a peripheral edge structure facilitating mutually exclusive processing of the upper and lower workpiece surfaces.

23. An apparatus as claimed in claim 21 wherein the workpiece is a generally circular semiconductor wafer and wherein the inlet openings of the upper and lower chamber members are generally aligned with the center of the semiconductor wafer.

24. An apparatus as claimed in claim 21 and further comprising one or more fasteners connecting the upper and lower chamber members, the one or more fasteners being adapted to allow relative movement between the upper and lower chamber members for accessing the processing chamber to insert and/or extract a workpiece.

25. A method for processing a workpiece comprising:

placing the workpiece in a substantially closed processing chamber of a workpiece housing;

providing a flow of fluid to a generally central portion of the processing chamber;

rotating the workpiece housing to generate centripetal acceleration that distributes the flow of fluid across at least one surface of the workpiece.

26. A method for processing a workpiece having upper and lower generally planar surfaces, the method comprising comprising:

placing the workpiece in a substantially closed processing chamber of a workpiece housing;

providing a first flow of fluid to a generally central upper portion of the processing chamber;

providing a second flow of fluid to a generally central lower portion of the processing chamber;

rotating the workpiece housing to generate centripetal acceleration that distributes the first flow of fluid across at least the upper surface of the workpiece and that distributes the second flow of fluid across at least the lower surface of the workpiece.

27. A method as claimed in claim 26 wherein the first and second flows of fluid are supplied concurrently.

28. A method as claimed in claim 27 and further comprising the step of separating the first and second flows of fluid so that above first flow of fluid principally contacts the upper surface of the workpiece to the general exclusion of the lower surface thereof and the second flow of fluid principally contacts the lower surface of the workpiece to the general exclusion of the upper surface thereof.

29. An apparatus for batch processing a plurality of workpieces in individual micro-environments, the apparatus comprising:

a rotor motor;

a plurality of workpiece housings, each connected for rotation by the rotor motor about a common rotation axis, each of the workpiece housings including therein a substantially closed processing chamber in which one or more processing fluids are distributed across at least one face of a respective one of the workpieces by centripetal accelerations generated during rotation of the housings.

30. An apparatus as claimed in claim 29 wherein each of the workpiece housings includes a centrally disposed inlet for supplying fluid to the respective processing chamber, the apparatus further comprising:

a stationary manifold;

a rotating manifold having an input connected to receive fluid from the outlet of the stationary manifold;

a plurality of fluid supply lines extending from and connected to the rotating manifold and terminating at one or more fluid outlets proximate the centrally disposed inlet of at least respective processing chamber.

31. An apparatus as claimed in claim 30 wherein the rotating manifold is connected for co-rotation with the workpiece housings.

32. An apparatus for processing a workpiece comprising:

a housing including a clean master processing chamber;

a robotic arm disposed in the clean master processing chamber and adapted to convey the workpiece;

a plurality of workpiece processing stations disposed in the clean master processing chamber at positions accessible by the robotic arm, at least one of the workpiece processing stations comprising

a rotor motor;

a workpiece housing connected for rotation by the rotor motor, the workpiece housing including therein a substantially closed processing chamber in which one or more processing fluids are distributed across at least one face of the workpiece by centripetal acceleration generated during rotation of the housing.

33. An apparatus as claimed in claim 32 wherein the workpiece housing further comprises:

at least one fluid inlet opening to the processing chamber and aligned with an axis of rotation of the housing; and

at least one fluid outlet extending from the processing chamber, the at least one fluid outlet positioned to allow escape of fluid from the processing chamber through action of centripetal acceleration generated during rotation of the workpiece housing about the axis of rotation.

34. An apparatus as claimed in claim 33 wherein the at least one fluid inlet opening is disposed through an upper portion of the processing chamber to thereby facilitate distribution of a fluid across an upper face of the workpiece through the action of centripetal acceleration.

35. An apparatus as claimed in claim 33 wherein the at least one fluid inlet opening is disposed through a lower portion of the processing chamber to thereby facilitate distribution of a fluid across a lower face of the workpiece through the action of centripetal acceleration.

36. An apparatus as claimed in claim 32 wherein the workpiece housing is a transportable pod.

37. An apparatus as claimed in claim 32 wherein the workpiece housing comprises upper and lower chamber members connected to one another to define the substantially closed processing chamber.

38. An apparatus as claimed in claim 32 wherein the workpiece housing comprises:

an upper chamber member having an interior chamber face, the upper chamber member including a centrally disposed fluid inlet opening in the interior chamber face thereof;

a lower chamber member having an interior chamber face, the lower chamber member including a centrally disposed fluid inlet opening in the interior chamber face thereof;

the upper chamber member and the lower chamber member being joined to one another to form the substantially closed processing chamber, the processing chamber generally conforming to the shape of the workpiece, the substantially closed processing chamber having at least one fluid outlet disposed at a peripheral region thereof to facilitate escape of fluid from the processing chamber through action of centripetal acceleration.

39. An apparatus as claimed in claim 38 wherein the workpiece housing further comprises:

at least one workpiece support adapted to support a workpiece in the substantially closed processing chamber in a position spaced from and generally parallel to the interior chamber face of the upper and lower chamber members, the workpiece support positioning the workpiece within the processing chamber to allow distribution of a fluid supplied through the inlet opening of the upper chamber member across at least an upper face of the workpiece through the action of centripetal acceleration, and to allow distribution of a fluid supplied through the inlet opening of the lower chamber member across at least a lower face of the workpiece through the action of centripetal acceleration.

40. An apparatus as claimed in claim 32 wherein the workpiece housing comprises:

an upper chamber inlet for supplying a first fluid flow into an upper region of the processing chamber for distribution of the first fluid flow across at least an upper surface of the workpiece through the action of centripetal acceleration; and

a lower chamber inlet for supplying a second fluid flow into a lower region of the processing chamber for distribution of the second fluid flow across at least a lower surface of the workpiece through the action of centripetal acceleration.

41. An apparatus as claimed in claim 40 and further comprising a dividing member disposed in the processing chamber about a peripheral edge of the workpiece at a position in which the dividing structure separates distribution flow of the first and second fluid flows, whereby the first fluid flow is principally limited to contacting the upper face of the workpiece and the second fluid flow is principally limited to contacting the lower face of the workpiece.

42. An apparatus for processing a workpiece in a micro-environment, the apparatus comprising:

enclosure means for enclosing a workpiece in a substantially closed processing chamber;

means for rotating the enclosure means, including the substantially closed processing chamber, to distribute one or more processing fluids across at least one face of the workpiece by centripetal acceleration generated during rotation of the enclosure means.

43. An apparatus as claimed in claim 42 wherein the enclosure means comprises fluid inlet means for providing a fluid to at least one of an upper or lower surface of the workpiece for distribution through the action of the centripetal acceleration.

44. An apparatus as claimed in claim 42 and further comprising means for opening and closing the enclosure means to thereby allow insertion and extraction of a workpiece for processing in the processing chamber.

45. An apparatus as claimed in claim 42 wherein the enclosure means comprises fluid outlet means for allowing escape of fluid from the processing chamber through action of centripetal acceleration generated during rotation of the enclosure means.

46. An apparatus as claimed in claim 42 wherein the enclosure means comprises means for providing first and second fluid flows to respective upper and lower surfaces of the workpiece.

47. An apparatus as claimed in claim 46 wherein the enclosure means comprises fluid dividing means disposed in the processing chamber for separating flow of the first and second fluid flows, whereby the first fluid

flow is principally limited to contacting the upper surface of the workpiece and the second fluid flow is principally limited to contacting the lower surface of the workpiece.

48. An apparatus for processing a microelectronic workpiece in a micro-environment comprising:

a first chamber member having an interior chamber wall;

a second chamber member having an interior chamber wall, the first and second chamber members being adapted for relative movement between a loading position in which the first and second chamber members are distal one another and a processing position in which the first and second chamber members are proximate one another to define a processing chamber;

at least one workpiece support assembly disposed between the first and second chamber members for supporting the microelectronic workpiece, the at least one workpiece support assembly being operable to space the microelectronic workpiece a first distance, x1, from an interior chamber wall of at least one of the first and second chamber members when the first and second chamber members are in the loading position and to space the microelectronic workpiece a second distance, x2, from the interior chamber wall when the first

and second chamber members are in the processing position, wherein x1 > x2.

49. An apparatus has claimed in claim 48 wherein the workpiece support assembly comprises:

a workpiece support member;

a biasing member disposed to engage the workpiece support member, the biasing member urging the workpiece support member to space the microelectronic workpiece the first distance, x1, from the interior chamber wall when the first and second chamber members are in the loading position, relative movement between the first and second chamber members urging the workpiece support member against the bias of the biasing member to drive the workpiece support member to space the microelectronic workpiece the second distance, x2, from the interior chamber wall when the first and second chamber members are in the processing position.

50. An apparatus as claimed in claim 49 wherein the biasing member is a coil spring actuator.

51. An apparatus as claimed in claim 49 wherein the biasing member is a leaf spring.

52. An apparatus as claimed in claim 48 wherein the workpiece support assembly comprises:

a workpiece support member movable between a first position in which the workpiece support member spaces the microelectronic workpiece the first distance, x1, from the interior chamber wall when the first and second chamber members are in the loading position, relative movement between the first and second chamber members urging the workpiece support member to drive the workpiece support member to space the microelectronic workpiece the second distance, x2, from the interior chamber wall when the first and second chamber members are in the processing position.

53. An apparatus as claimed in claim 48 and further comprising:

at least one processing fluid inlet disposed through at least one of the interior chamber walls for communicating processing fluid to contact the microelectronic workpiece when the first and second chamber members are in the processing position;

a rotor motor connected to rotate the first and second chamber members about a rotation axis to thereby distribute the processing fluid over a surface of the microelectronic workpiece through the action of centripetal acceleration generated during the rotation.

54. An apparatus as claimed in claim 49 and further comprising:

at least one processing fluid inlet disposed through at least one of the interior chamber walls for communicating processing fluid to contact the microelectronic workpiece when the first and second chamber members are in the processing position;

a rotor motor connected to rotate the first and second chamber members about a rotation axis to thereby distribute the processing fluid over a surface of the microelectronic workpiece through the action of centripetal acceleration generated during the rotation.

55. An apparatus as claimed in claim 50 and further comprising:

at least one processing fluid inlet disposed through at least one of the interior chamber walls for communicating processing fluid to contact the microelectronic workpiece when the first and second chamber members are in the processing position;

a rotor motor connected to rotate the first and second chamber members about a rotation axis to thereby distribute the processing fluid over a surface of the microelectronic workpiece through the action of centripetal acceleration generated during the rotation.

56. An apparatus as claimed in claim 51 and further comprising:

a processing fluid inlet disposed through at least one of the interior chamber walls for communicating processing fluid to contact the microelectronic workpiece when the first and second chamber members are in the processing position;

a rotor motor connected to rotate the first and second chamber members about a rotation axis to thereby distribute the processing fluid over a surface of the microelectronic workpiece through the action of centripetal acceleration generated during the rotation.

57. An apparatus for processing a microelectronic workpiece in a micro-environment, the apparatus comprising:

an upper chamber member having an interior chamber wall ;

a lower chamber member having an interior chamber wall;

the upper chamber member and the lower chamber being adapted for relative movement between a loading position in which the upper and lower

chamber members are distal one another and a processing position in which the upper and lower chamber members are effectively joined to one another to form a substantially closed processing chamber generally conforming to the shape of the microelectronic workpiece, the substantially closed processing chamber having at least one fluid outlet disposed at a peripheral region thereof;

at least one processing fluid inlet disposed through at least one of the interior chamber walls for communicating processing fluid to contact a face of the microelectronic workpiece when the upper and lower chamber members are in the processing position;

a workpiece support assembly disposed between the upper and lower chamber members for supporting the microelectronic workpiece, the workpiece support assembly being operable to space the microelectronic workpiece a first distance, x1, from an interior chamber wall of at least one of the first and second chamber members when the first and second chamber members are in the loading position and to space the microelectronic workpiece a second distance, x2, from the interior chamber wall when the first and second chamber members are in the processing position, wherein x1 > x2, the at least one workpiece support adapted to support the microelectronic workpiece in the substantially closed

processing chamber in a position to allow distribution of a fluid supplied through the at least one processing fluid inlet across at least one face of the microelectronic workpiece through the action of centripetal acceleration.

58. An apparatus as claimed in claim 57 wherein the at least one processing fluid inlet is disposed through the interior chamber wall of the upper chamber member to communicate processing fluid for distribution across an upper surface of the microelectronic workpiece, the apparatus further comprising a further processing fluid inlet disposed through the interior chamber wall of the lower chamber member to communicate processing fluid for distribution across a lower surface of the microelectronic workpiece.

59. An apparatus as claimed in claim 57 wherein the workpiece support assembly comprises:

a workpiece support member;

a biasing member disposed to engage the workpiece support member, the biasing member urging the workpiece support member to space the microelectronic workpiece the first distance, x1, from the interior chamber wall when the first and second chamber members are in the

loading position, relative movement between the first and second chamber members urging the workpiece support member against the bias of the biasing member to drive the workpiece support member to space the microelectronic workpiece the second distance, x2, from the interior chamber wall when the first and second chamber members are in the processing position

60. An apparatus as claimed in claim 57 wherein the workpiece support assembly comprises:

a plurality of workpiece support members each having an upstanding portion and a support surface;

a biasing member disposed to engage the upstanding portions of the plurality workpiece support member, the biasing member urging the workpiece support member to space the microelectronic workpiece the first distance, x1, from the interior chamber wall when the first and second chamber members are in the loading position, relative movement between the first and second chamber members urging the workpiece support member against the bias of the biasing member to drive the workpiece support member to space the microelectronic workpiece the second distance, x2, from the interior chamber wall when the first and second chamber members are in the processing position.

61. An apparatus as claimed in claim 60 wherein the biasing member comprises a plurality of leaf spring members extending from a central hub, end portions of the leaf spring members contacting respective upstanding members of the workpiece supports

62. An apparatus as claimed in claim 61 wherein the plurality of workpiece support members are disposed through the lower chamber member and wherein the biasing member is secured to the lower chamber member at the hub of the biasing member by a securement that forms the processing fluid inlet of the lower chamber member.

63. An apparatus for processing a microelectronic workpiece comprising:

a rotor assembly adapted to support the workpiece and rotate with the microelectronic workpiece during microelectronic workpiece processing;

a processing head adapted to rotate the rotor assembly during microelectronic workpiece processing; and

a connector hub assembly including threaded hub members, the threaded hub members securing the rotor assembly for rotation by the processing head screwed together and allowing separation between

the rotor assembly and processing head via a screw in the threaded hub members.

64. An apparatus as claimed in claim 63 wherein the threaded hub members comprise:

a first hub member in fixed engagement with the processing head;

a second hub member in fixed engagement with the rotor assembly, the first and second hub of members having corresponding threads allowing the first and second hub members to be readily joined to and separated from one another, the first and second of members being joined for co-rotation during microelectronic workpiece processing;

a locking mechanism for securing the first hub member with the processing head to prevent co-rotation of the first and second hub members thereby allowing the second hub member to be on screwed from the first hub member to remove the rotor assembly.

65. An apparatus for processing a workpiece in a micro-environment, the apparatus comprising:

a plurality of walls defining a substantially closed rinser/dryer chamber, the substantially closed rinser/dryer chamber having at least one fluid outlet disposed at a peripheral region thereof, and at least one fluid inlet disposed to allow a fluid to enter the rinser/dryer chamber at a non-peripheral region;

at least one workpiece support adapted to support a workpiece in the substantially closed rinser/dryer chamber in a position to allow distribution of a fluid supplied through the fluid inlet across at least one face of the workpiece through action of centripetal acceleration, the at least one fluid outlet being positioned to allow escape of fluid from the rinser/dryer chamber through action of centripetal acceleration;

a fluid supply system connected to sequentially supply a rinsing fluid followed by a drying fluid to the at least one inlet opening.

66. An apparatus as claimed in claim 65 wherein the at least one fluid inlet is disposed at a central portion of the rinser/dryer chamber.

67. An apparatus as claimed in claim 65 wherein the at least one fluid inlet is disposed at a central upper portion of the rinser/dryer chamber to supply a flow of fluid proximate an upper surface of the workpiece.

68. An apparatus as claimed in claim 65 wherein the at least one fluid inlet is disposed at a central lower portion of the rinser/dryer chamber to supply a flow of fluid proximate a lower surface of the workpiece.

69. An apparatus as claimed in claim 65 wherein the rinser/dryer housing comprises:

an upper chamber inlet for supplying a first fluid flow into an upper region of the rinser/dryer chamber for distribution of the first fluid flow across at least an upper surface of the workpiece through the action on centripetal acceleration; and

a lower chamber inlet for supplying a second fluid flow into a lower region of the rinser/dryer chamber for distribution of the second fluid flow across at least a lower surface of the workpiece through the action of centripetal acceleration.

70. An apparatus as claimed in claim 69 and further comprising a dividing structure disposed in the rinser/dryer chamber about a peripheral edge of the workpiece at a position in which the dividing structure separates distribution flow of the first and second fluid flows, whereby the first fluid flow is principally limited to contacting the upper face of the workpiece and

the second fluid flow is principally limited to contacting the lower face of the workpiece.

71. An apparatus as claimed in claim 65 wherein the substantially closed rinser/dryer chamber generally conforms to the shape of the workpiece.

72. An apparatus as claimed in claim 71 wherein the workpiece is a generally circular semiconductor wafer, the plurality of walls comprising:
a generally planar upper interior chamber face;
a generally planar lower interior chamber face;
the upper and lower interior chamber faces being disposed so as to be generally parallel with upper and lower planar surfaces of the semiconductor wafer, respectively.

73. An apparatus for rinsing and drying a workpiece in a micro-environment, the apparatus comprising:
an upper chamber member having a fluid inlet opening ;
a lower chamber member having a fluid inlet opening;
the upper chamber member and the lower chamber member being joined to one another to form a substantially closed rinser/dryer chamber

generally conforming to the shape of the workpiece, the substantially closed rinser/dryer chamber having at least one fluid outlet disposed at a peripheral region thereof;

at least one workpiece support adapted to support a workpiece in the substantially closed rinser/dryer chamber in a position to allow distribution of a fluid supplied through the inlet opening of the upper chamber member across at least an upper face of the workpiece through the action of centripetal acceleration, and to allow distribution of a fluid supplied through the inlet opening of the lower chamber member across at least a lower face of the workpiece through the action of centripetal acceleration, the at least one fluid outlet being positioned to allow escape of fluid from the rinser/dryer chamber through action of centripetal acceleration; and

a fluid supply system connected to sequentially supply a rinsing fluid followed by a drying fluid to the inlet opening of the upper chamber member and the inlet opening of the lower chamber member.

74. An apparatus as claimed in claim 73 wherein the rinsing fluid is principally comprised of DI water.

75. An apparatus as claimed in claim 74 wherein the drying fluid is principally comprised of nitrogen and IPA vapor.

76. An apparatus as claimed in claim 73 wherein the drying fluid is principally comprised of nitrogen and IPA vapor.

77. An apparatus as claimed in claim 73 and further comprising a peripheral edge structure facilitating mutually exclusive rinsing and drying of the upper and lower workpiece surfaces.

78. An apparatus as claimed in claim 73 wherein the workpiece is a generally circular semiconductor wafer and wherein the inlet openings of the upper and lower chamber members are generally aligned with the center of the semiconductor wafer.

79. An apparatus as claimed in claim 73 and further comprising one or more fasteners connecting the upper and lower chamber members, the one or more fasteners being adapted to allow relative movement between the upper and lower chamber members for accessing the rinser/dryer chamber to insert and/or extract a workpiece.

80. A method for rinsing and drying a workpiece comprising:

placing the workpiece in a substantially closed rinser/dryer chamber of a rinser/dryer housing;

providing a flow of rinsing fluid to a generally central portion of the rinser/dryer chamber;

rotating the rinser/dryer housing to generate centripetal acceleration that distributes the flow of rinsing fluid across at least one surface of the workpiece;

providing a flow of drying fluid to a generally central portion of the rinser/dryer chamber after the rinsing fluid; and

rotating the rinser/dryer housing to generate centripetal acceleration that distributes the flow of drying fluid across at least one surface of the workpiece.

81. A method as claimed in claim 80 wherein the rinsing fluid is principally comprised of DI water.

82. A method as claimed in claim 80 wherein the drying fluid is principally comprised of nitrogen and IPA vapor.

83. A method as claimed in claim 81 wherein the drying fluid is principally comprised of nitrogen and IPA vapor.

84. An apparatus for processing a workpiece comprising:

a housing including a clean master rinser/dryer chamber;

a robotic arm disposed in the clean master rinser/dryer chamber and adapted to convey the workpiece;

a plurality of workpiece processing stations disposed in the clean master rinser/dryer chamber at positions accessible by the robotic arm, at least one of the workpiece processing stations comprising

a rotor motor;

a rinser/dryer housing connected for rotation by the rotor motor, the rinser/dryer housing including therein a substantially closed rinser/dryer chamber in which one or more rinsing/drying fluids are distributed across at least one face of the workpiece by centripetal acceleration generated during rotation of the housing.

85. An apparatus as claimed in claim 84 wherein the rinser/dryer housing further comprises:

at least one fluid inlet opening to the rinser/dryer chamber and aligned with an axis of rotation of the housing; and

at least one fluid outlet extending from the rinser/dryer chamber, the at least one fluid outlet positioned to allow escape of fluid from the rinser/dryer chamber through action of centripetal acceleration generated during rotation of the rinser/dryer housing about the axis of rotation.

86. An apparatus as claimed in claim 85 wherein the at least one fluid inlet opening is disposed through an upper portion of the rinser/dryer chamber to thereby facilitate distribution of a fluid across an upper face of the workpiece through the action of centripetal acceleration.

87. An apparatus as claimed in claim 85 wherein the at least one fluid inlet opening is disposed through a lower portion of the rinser/dryer chamber to thereby facilitate distribution of a fluid across a lower face of the workpiece through the action of centripetal acceleration.

88. An apparatus as claimed in claim 84 wherein the rinser/dryer housing is a transportable pod.

89. An apparatus for processing a microelectronic workpiece having a front side, a back side, and an outer perimeter, the apparatus comprising:

a reactor having an upper chamber wall and a lower chamber wall, the reactor supporting a microelectronic workpiece in a processing position between the upper and lower chamber walls, the upper and lower chamber walls being rotatable conjointly with a microelectronic workpiece supported in the processing position, each of the upper and lower chamber walls having an inlet for processing fluids;

an upper processing chamber being defined by the upper chamber wall and by a microelectronic workpiece supported in the processing position;

a lower processing chamber being defined by the lower chamber wall and by a microelectronic workpiece supported in the processing position, the upper and lower processing chambers being in fluid communication with each other in a region beyond the outer perimeter of a microelectronic workpiece supported in the processing position;

a selected one of the upper and lower chamber walls having an outlet for processing fluids from the upper and lower chambers, the outlet

being spaced outwardly from a rotation axis by a radial distance and being spaced inwardly from the outer perimeter of a microelectronic workpiece supported in the processing position by a comparatively smaller radial distance, whereby processing fluids entering the inlet of the remaining one of the upper and lower chamber walls can act on the nearer of the front and back sides of the supported microelectronic workpiece, on the outer periphery of the supported microelectronic workpiece, and on an outer margin of the other side of the supported microelectronic workpiece before reaching the outlet and whereby processing fluids entering the inlet of the selected one of the upper and lower chamber walls can act on the latter side of the supported microelectronic workpiece, except for the outer margin of the latter side, before reaching the outlet.

90. The apparatus of claim 89 wherein the outlet is one of an array of similar outlets spaced similarly from the vertical axis and from the outer perimeter of a microelectronic workpiece supported in the processing position.

91. The apparatus of claim 89 wherein the selected one of the upper and lower chamber walls is the upper chamber wall.

92. The apparatus of claim 90 wherein the selected one of the upper and lower chamber walls is the upper chamber wall.

93. The apparatus of claim 89, 90, 91, or 92 wherein each outlet communicates with a coaxial, annular plenum having a drain, which is equipped with a valve for opening and closing the drain.

94. The apparatus of claim 93 wherein the drain is one of an array of drains, each of which is equipped with a valve for opening and closing the drain.

95. The apparatus of claim 89, 90, 91, or 92 wherein the upper and lower chamber walls when closed are sealed by an annular, compressible seal.

96. The apparatus of claim 93 wherein the upper and lower chamber walls when closed are sealed by an annular, compressible seal above the plenum.

97. The apparatus of claim 94 wherein the upper and lower chamber walls when closed are sealed by an annular, compressible seal above the plenum.

98. The apparatus of claim 93 wherein an annular skirt extends around and downwardly from the upper chamber wall, above the plenum, so as to be

conjointly rotatable with the upper chamber wall, and wherein each outlet is oriented so as to direct processing fluids exiting said outlet against an inner surface of the annular skirt.

99. The apparatus of claim 98 wherein the inner surface of the skirt is flared outwardly and downwardly so as to cause processing fluids reaching the inner surface to flow outwardly and downwardly toward the plenum, via centripetal acceleration.

100. The apparatus of claim 94 wherein an annular skirt extends around and downwardly from the upper chamber wall, above the plenum, so as to be conjointly rotatable with the upper chamber wall, and wherein each outlet is oriented so as to direct processing fluids exiting said outlet against an inner surface of the annular skirt.

101. The apparatus of claim 100 wherein the inner surface of the skirt is flared outwardly and downwardly so as to cause processing fluids reaching the inner surface to flow outwardly and downwardly toward the plenum, via centripetal acceleration.

102. An apparatus for processing a microelectronic workpiece having a front side, a back side, and an outer perimeter, the apparatus comprising:

a reactor having an upper chamber wall and a lower chamber wall, the upper and lower chamber walls being arranged to open so as to permit a microelectronic workpiece to be loaded into the reactor for processing and to removed from the reactor, to close so as to support a microelectronic workpiece in a processing position, between the upper and lower chamber walls, the upper and lower chamber walls being rotatable when closed, around a vertical axis, conjointly with a microelectronic workpiece supported in the processing position;

the upper and lower chamber walls being clamped releasably to each other when closed by a latching mechanism including a latching ring retained by a selected one of the upper and lower chamber walls and adapted to fit removably into a complementarily shaped recess in the remaining one of the upper and lower chamber walls.

103. The apparatus of claim 102 wherein the latching ring is made from a spring material with an array of inwardly stepped portions, said portions of the latching ring enabling the latching ring to deform from an undeformed

condition wherein the latching ring has a comparatively larger diameter into a deformed condition wherein the latching ring has a comparatively smaller diameter when said portions of the latching ring are pulled in radial inward directions, saidportions of the latching ring enabling the latching ring to return to the undeformed condition when said portions of the latching ring are released.

104. The apparatus of claim 103 wherein the latching mechanism further includes an array of latching cams, each associated with a respective one of said portions of the latching ring, each adapted when actuated to pull the associated one of said portions of the latching ring in a radially inward direction, and each adapted when deactuated to release the associated one of the said portions of the latching ring.

105. The apparatus of claim 104 wherein the latching mechanism further includes an actuating ring adapted to being raised and lowered within a limited range of movement of the actuating ring, adapted when raised to actuate said cams, and adapted when lowered to deactuate said cams.

106. The apparatus of claim 105 wherein the latching mechanism further includes an array of pneumatic devices adapted when actuated to raise the actuating ring.

107. The apparatus of claim 106 wherein the actuating ring is adapted to be pneumatically lowered when said devices are deactuated.

108. An apparatus for processing a microelectronic workpiece having a front side, a back side, and an outer perimeter, the apparatus comprising:

a reactor having an upper chamber wall and a lower chamber wall, the reactor being adapted to support a microelectronic workpiece in a processing position between the upper and lower chamber walls, the upper and lower chamber walls being rotatable about a rotation axis conjointly with a microelectronic workpiece supported in the processing position, each of the upper and lower chamber walls having an inlet for processing fluids;

an upper processing chamber defined by the upper chamber wall and by a microelectronic workpiece supported inthe processing position;

a lower processing chamber defined by the lower chamber wall and by a microelectronic workpiece supported in the processing position, the upper and lower processing chambers being in fluid communication

with each other in a region beyond the outer perimeter of a microelectronic workpiece supported in the processing position;

a selected one of the upper and lower chamber walls having an outlet for processing fluids from the upper and lower chambers, the outlet being spaced outwardly from the rotation axis;

the lower chamber wall having an upper surface shaped so as to define an annular sump around the inlet of the lower chamber wall, for collecting liquids from processing fluids entering the inlet of the lower chamber wall, if the liquids strike and drop from a microelectronic workpiece supported in the processing position, and for conducting the collected liquids toward the outlet when centripetal acceleration is imparted to the collected liquids.

109. The apparatus of claim 108 wherein a nozzle is provided beneath the inlet of the lower chamber wall, for directing streams of processing fluids upwardly through the inlet of the lower chamber wall.

110. The apparatus of claim 109 wherein the nozzle has plural ports for directing plural streams of processing fluids simultaneously and upwardly through the inlet of the lower chamber wall.

111. The apparatus of claim 110 wherein said ports are oriented so as to cause the directed streams to converge approximately where the directed streams reach a microelectronic workpiece supported in the processing position.

112. The apparatus of claim 109, 110, or 111 wherein another nozzle is provided to one side of the nozzle provided beneath the inlet of the lower chamber wall, for directing a stream of purging gas across the nozzle provided beneath the inlet of the lower chamber wall.

113. An apparatus for processing a microelectronic workpiece having a front side, a back side, and an outer, circular perimeter, the apparatus comprising:

a reactor having an upper chamber wall and a lower chamber wall, the upper and lower chamber walls being arranged to open so as to permit a microelectronic workpiece to be loaded into the reactor for processing and to removed from the reactor, to close so as to support a microelectronic workpiece in a processing position, between the upper and lower chamber walls, the upper and lower chamber walls being rotatable when closed around a vertical axis conjointly with a microelectronic workpiece supported in the

processing position, each of the upper and lower chamber walls having an inlet for processing fluids;

an upper processing chamber being defined by the upper chamber wall and by a microelectronic workpiece supported in the processing position;

a lower processing chamber being defined by the lower chamber wall and by a microelectronic workpiece supported in the processing position, the upper and lower processing chambers communicating with each other in an annular region beyond the outer perimeter of a microelectronic workpiece supported in the processing position;

a selected one of the upper and lower chamber walls having an outlet for processing fluids from the upper and lower chambers, the outlet being spaced outwardly from the vertical axis, the lower chamber wall having spacers for spacing a microelectronic workpiece supported in the processing position above the lower chamber wall by a given distance;

the lower chamber wall mounting a lifting mechanism for lifting a microelectronic workpiece supported in the processing position to an elevated position, at a greater distance above the lower chamber wall, when the upper and lower chamber walls are opened.

114. The apparatus of claim 113 wherein the lifting mechanism includes an array of lifting levers, each pivotable between an operative position and an inoperative position and biased so as to pivot into the operative position, each adapted to pivot from the operative position into the inoperative position when the upper and lower chamber walls are closed and from the inoperative position into the operative position when the upper and lower chamber walls are opened, each having a projection adapted to project beneath a microelectronic workpiece supported in theprocessing position and to lift the supported microelectronic workpiece when pivoted from the inoperative position into the operative position.

115. The apparatus of claim 114 herein the lifting levers are biased by an elastic member engaging the lifting levers and maintained under comparatively higher tension when the upper and lower chamber walls are closed and under comparatively lower tension when the upper and lower chamber walls are opened.

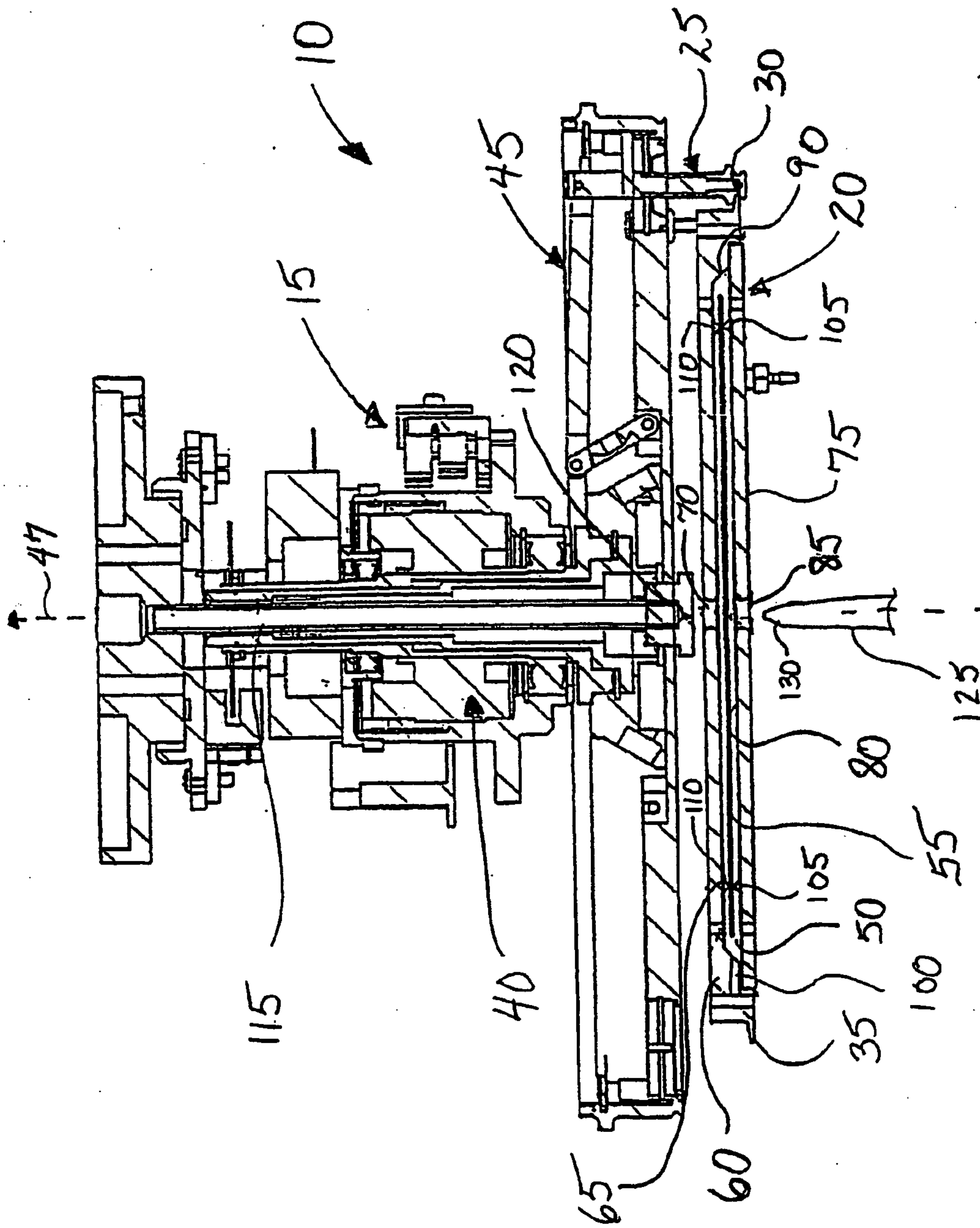
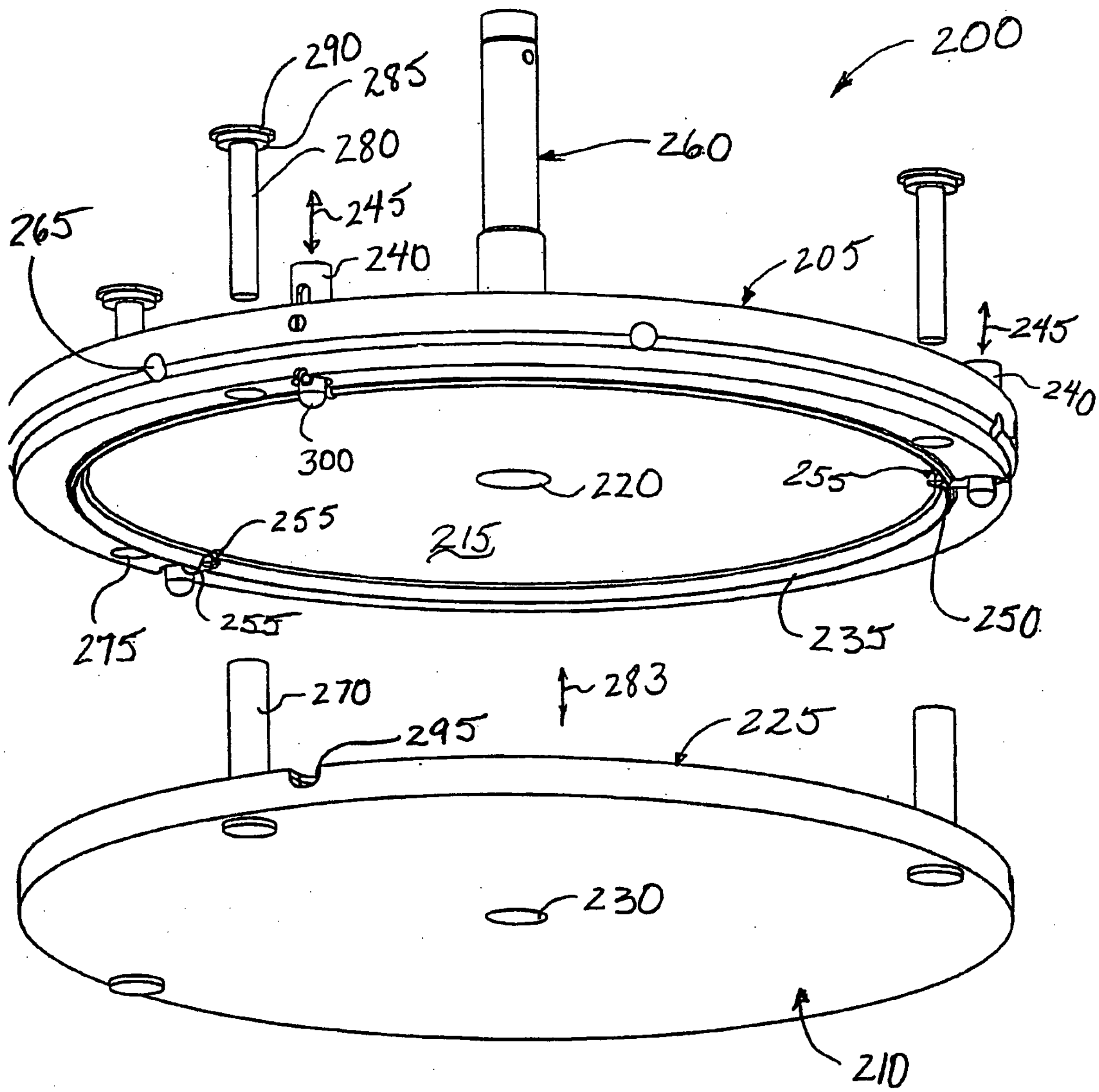

10
15
20
25
30
35
40
45
47
50
55
60
65
70
75
80
85
90
100
105
105
110
110
115
120
125
130

FIG. 1

FIG. 2


200
290
285
280
260
245
240
265
205
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240
300
220
255
255
215
255
275
235
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283
295
225
230
210

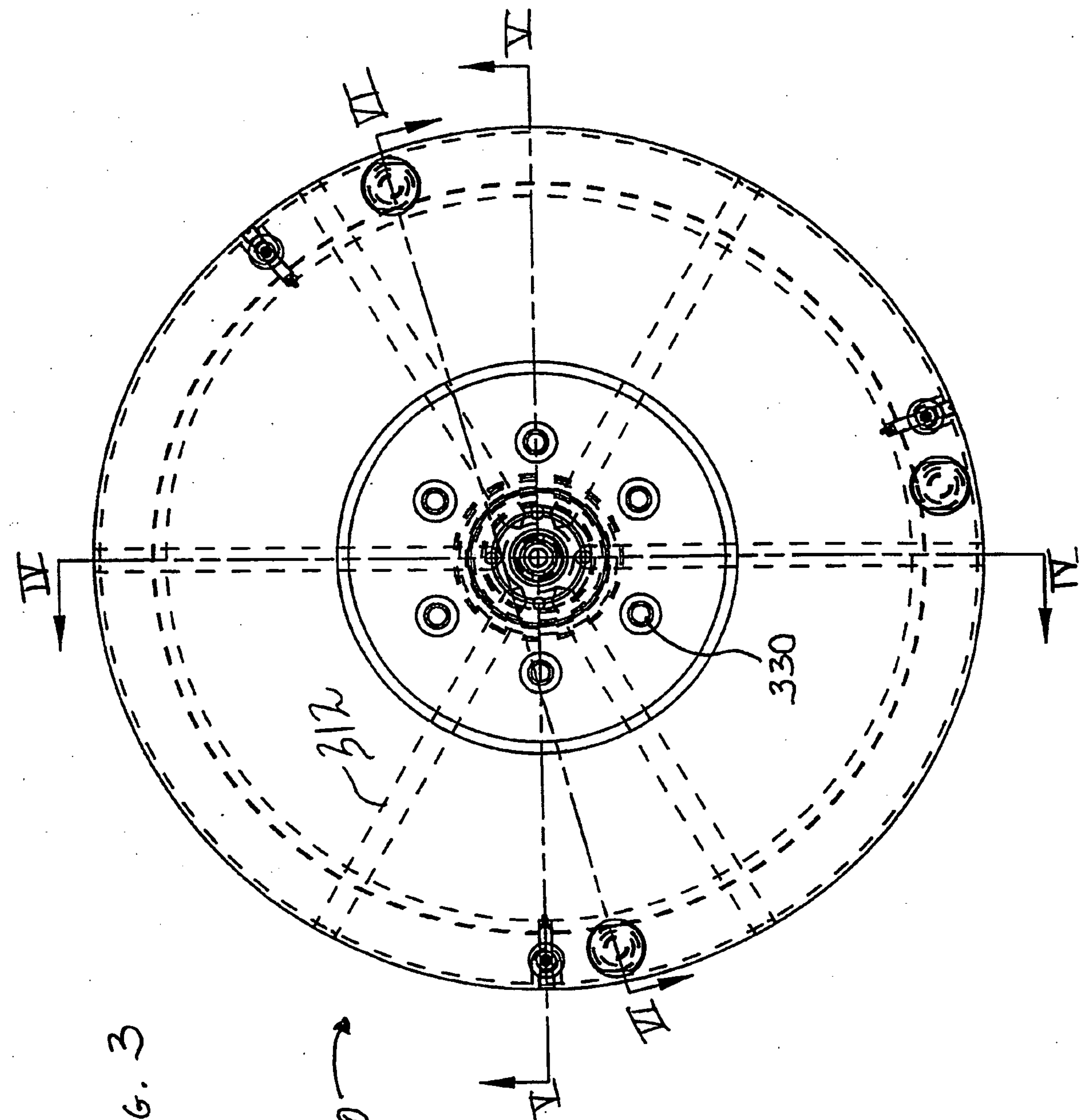


FIG. 3

Fig. 4

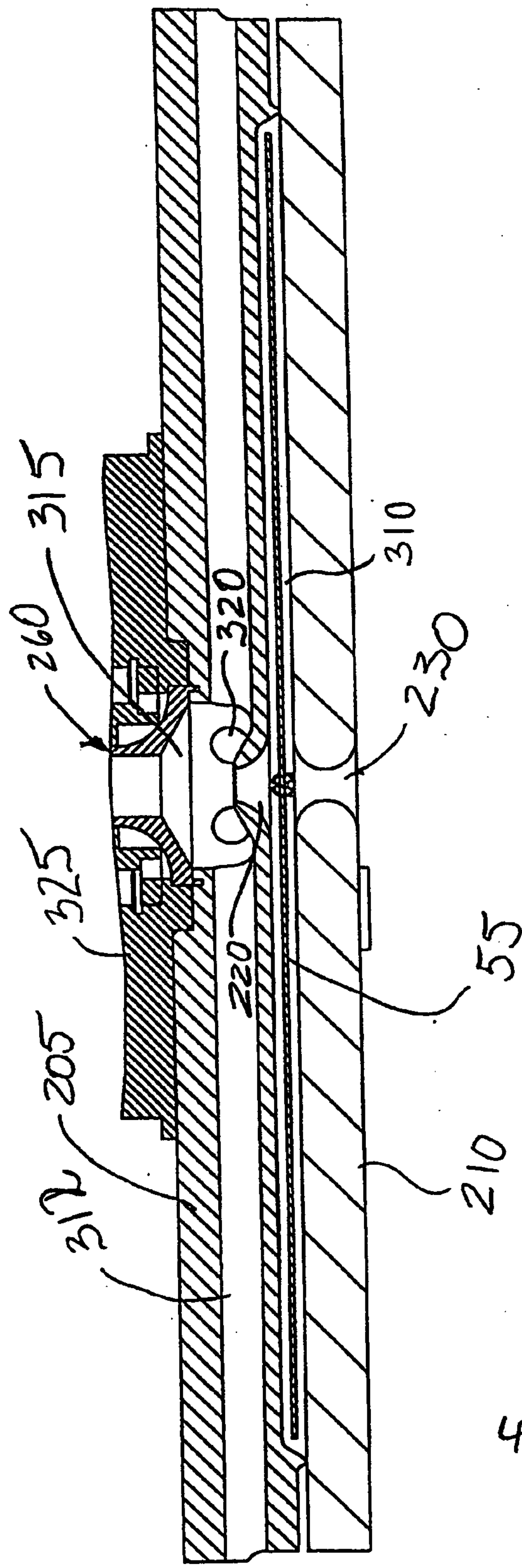
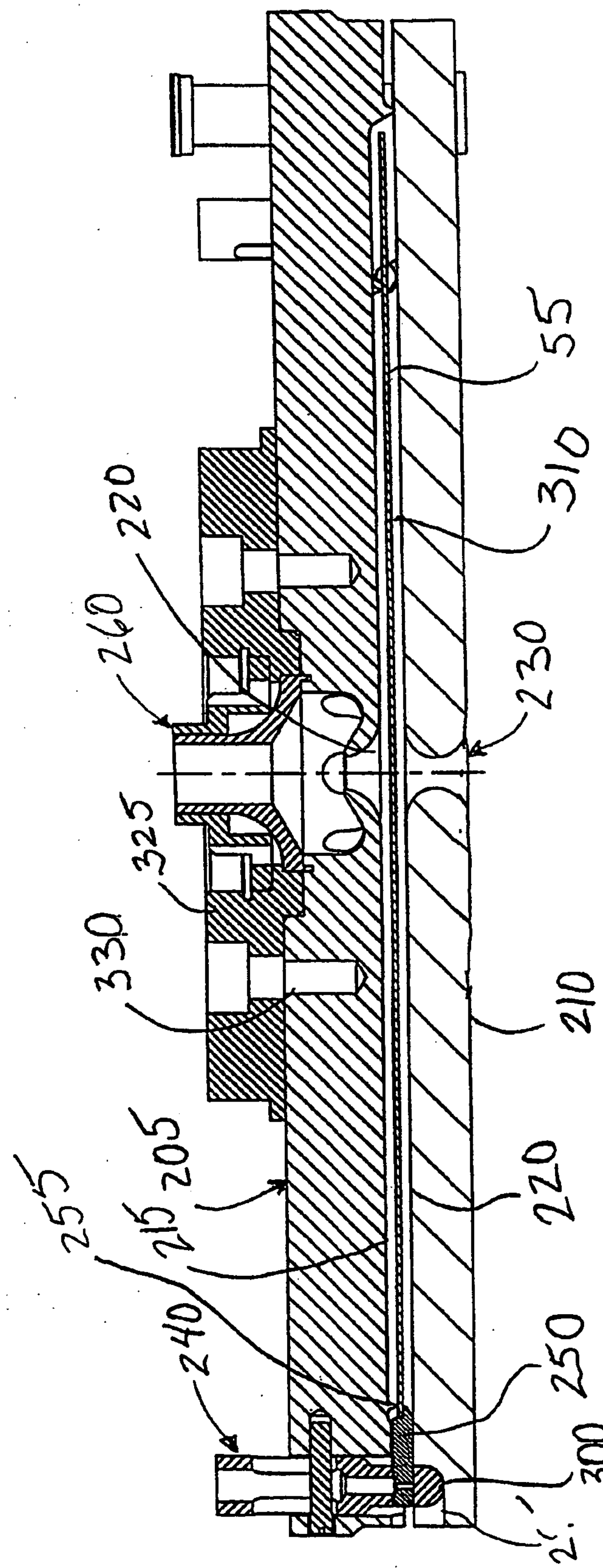


FIG. 5



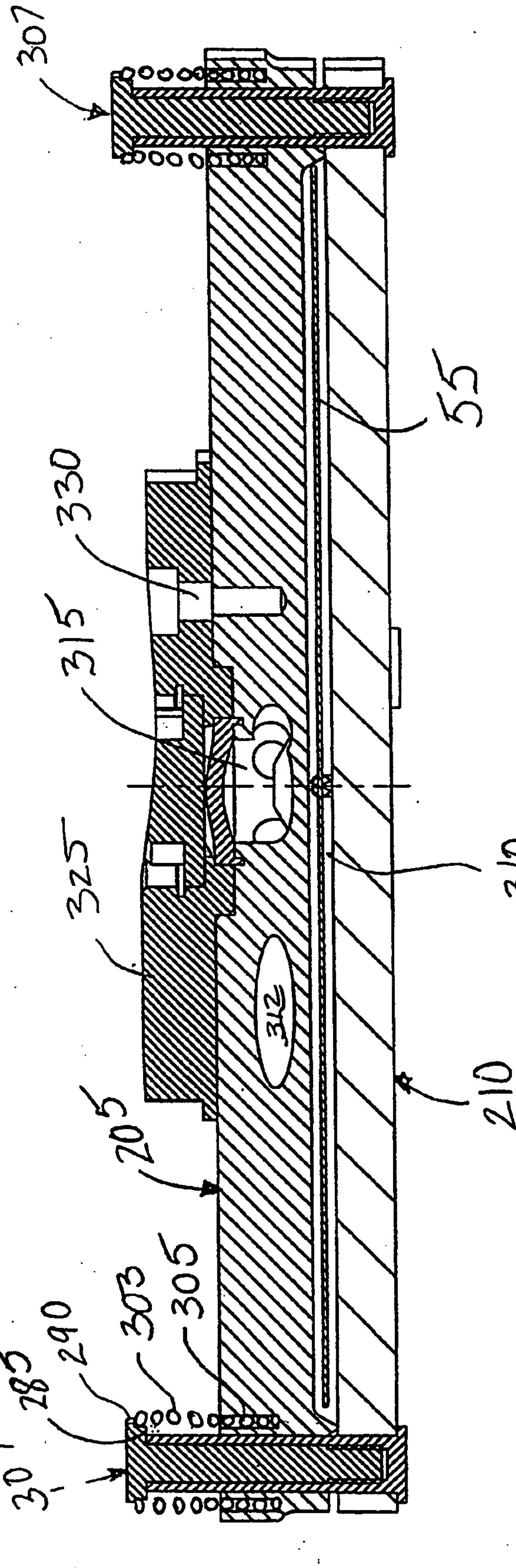


FIG. 6

FIG. 7A

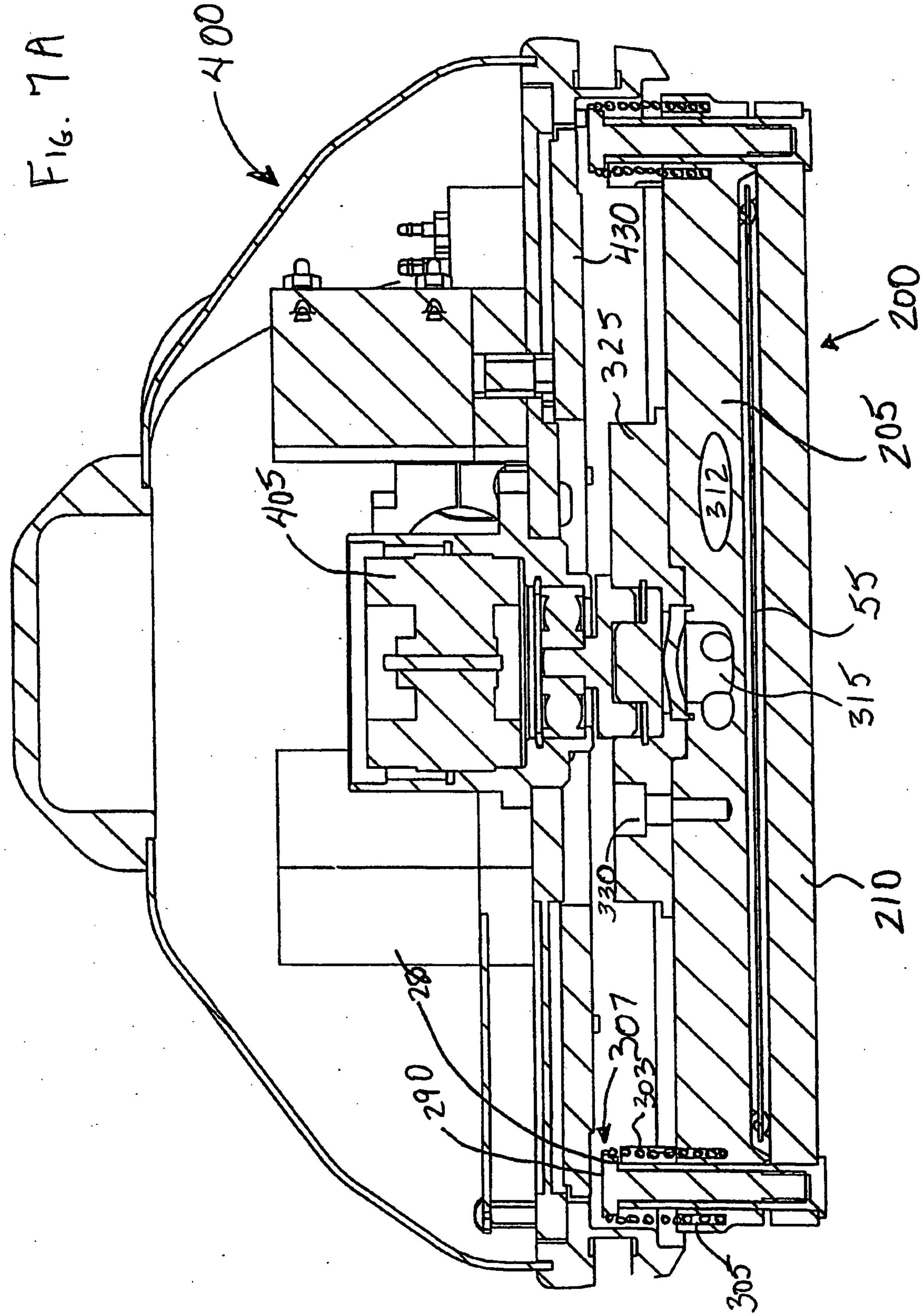
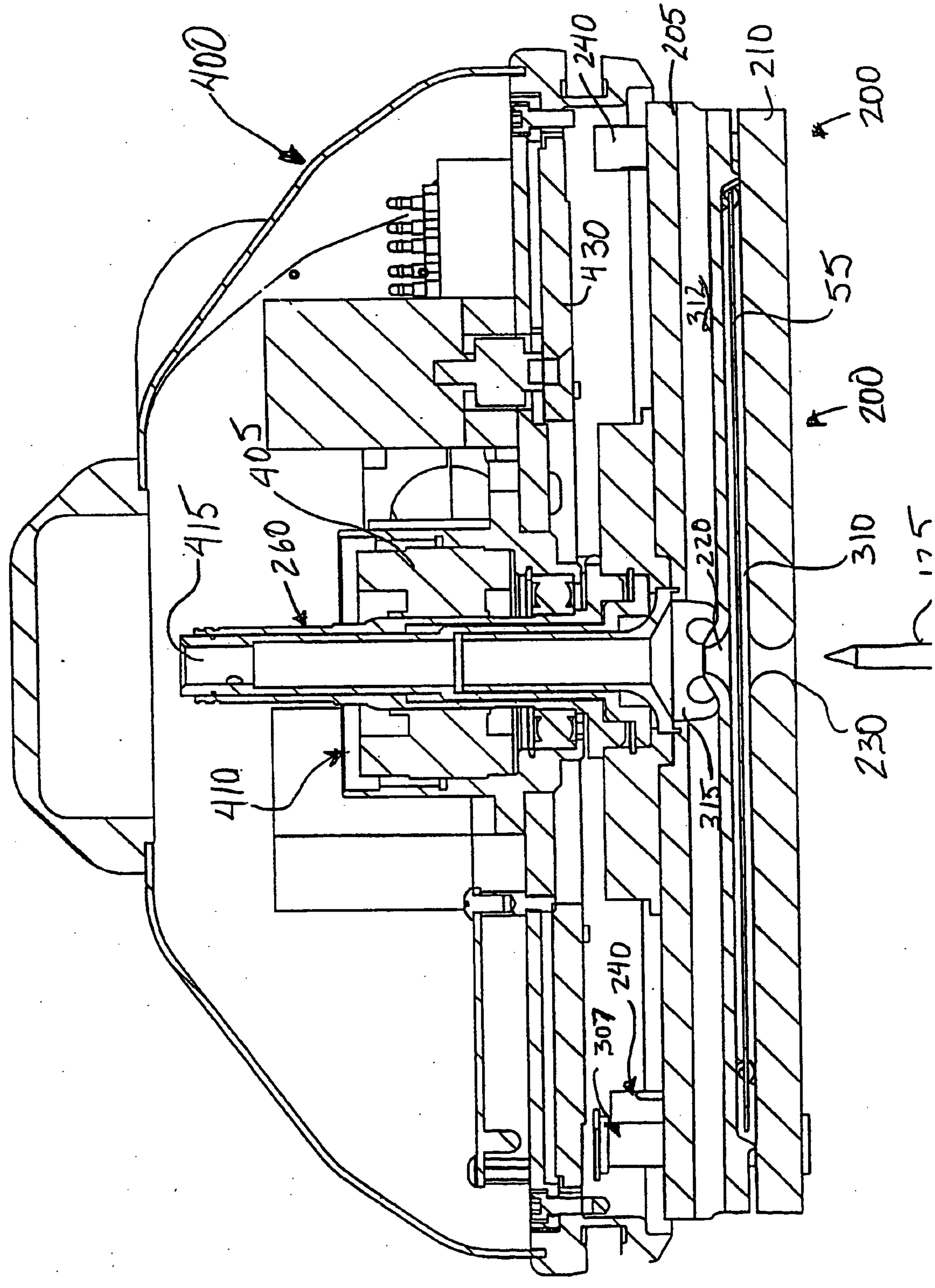


FIG. 7B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240
205
210
200
430
312
55
200
405
415
260
220
310
175
410
315
230
307
240

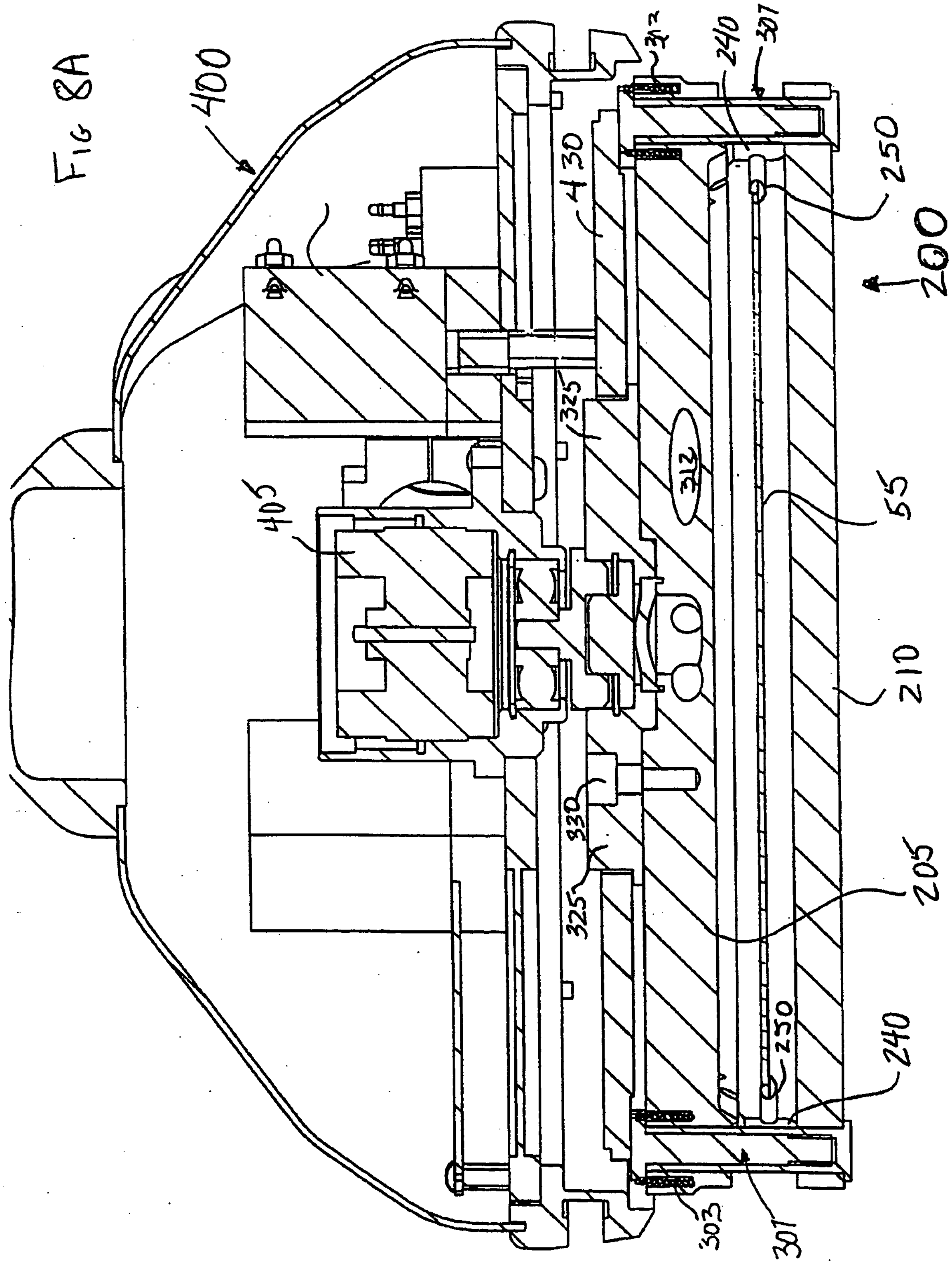
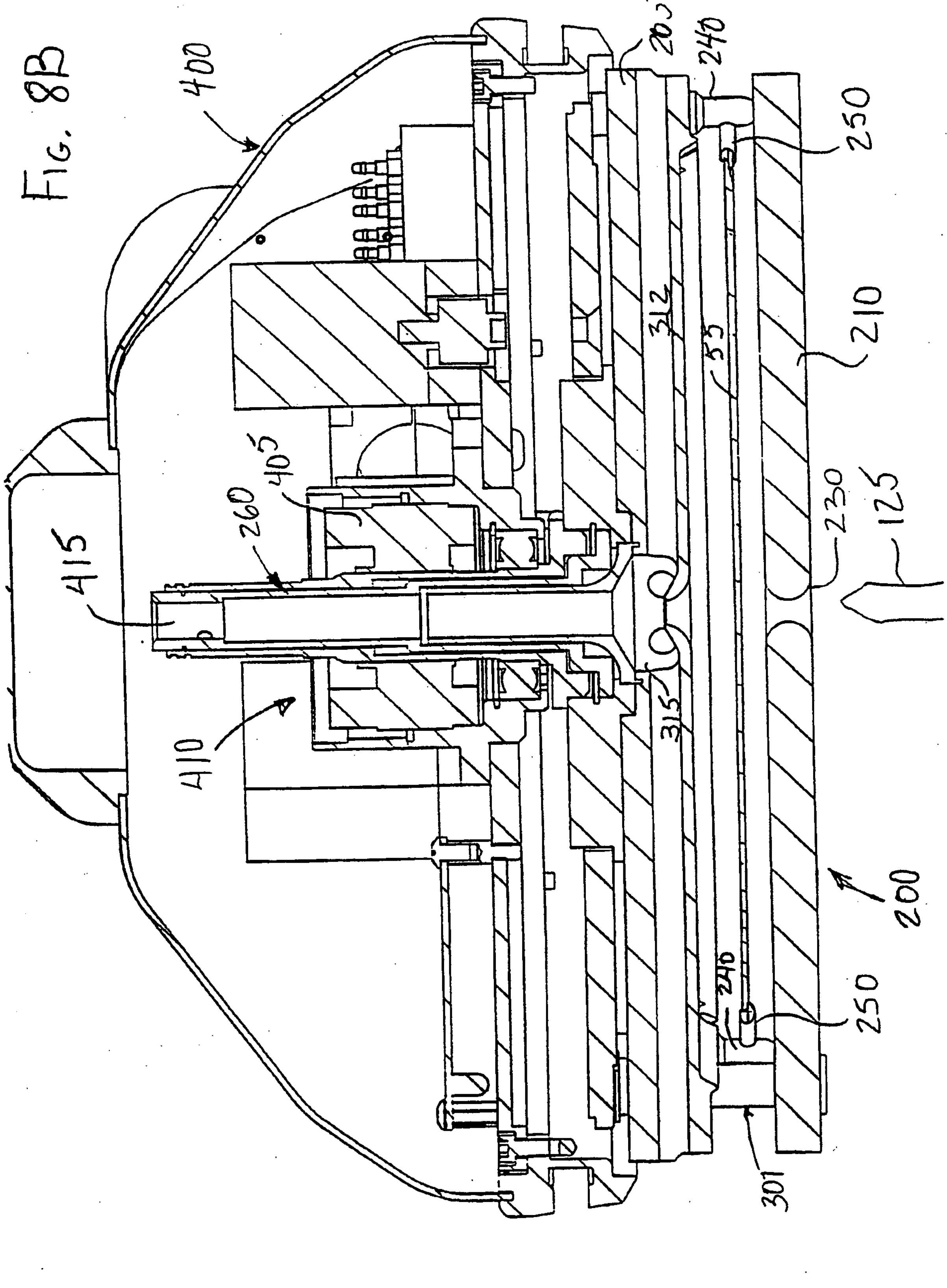


FIG 8A
400
430
312
240
301
250
200
325
312
55
405
210
330
325
205
250
240
303
301


400
415
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410
205
240
250
312
55
210
230
125
315
200
240
250
301

FIG. 8B

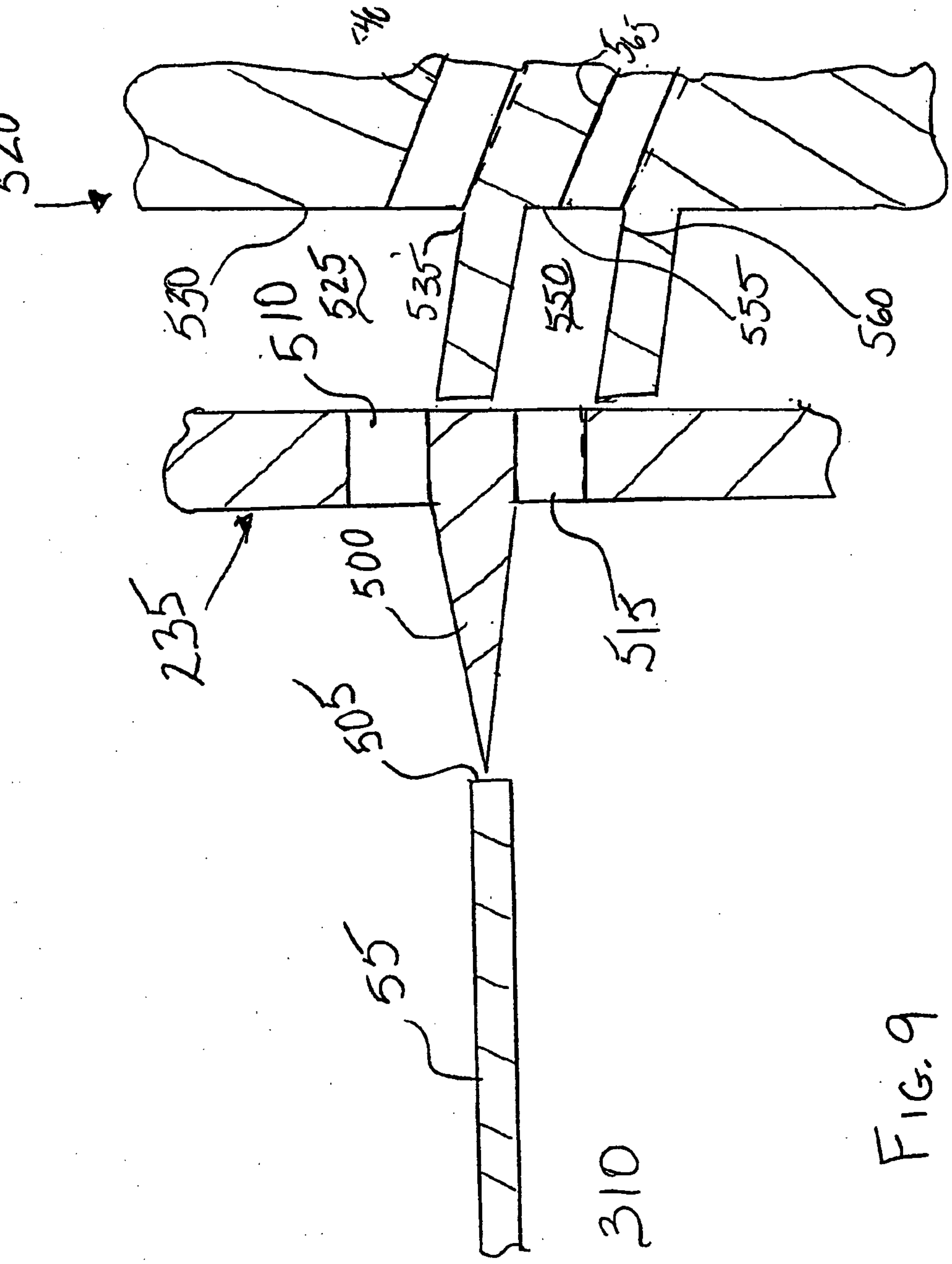
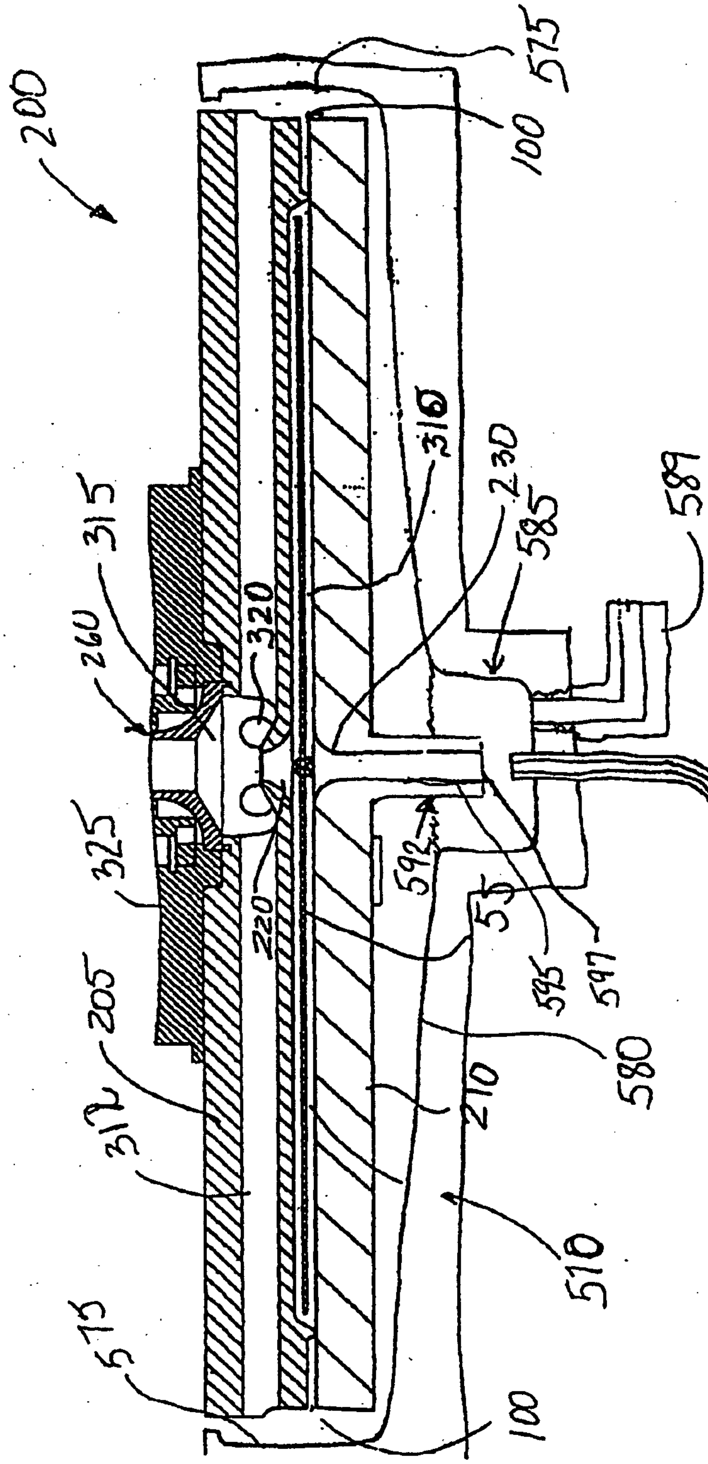


FIG. 9


200
575
100
316
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589
315
260
320
325
205
312
220
592
595
597
587
580
210
510
575
100

FIG. 10

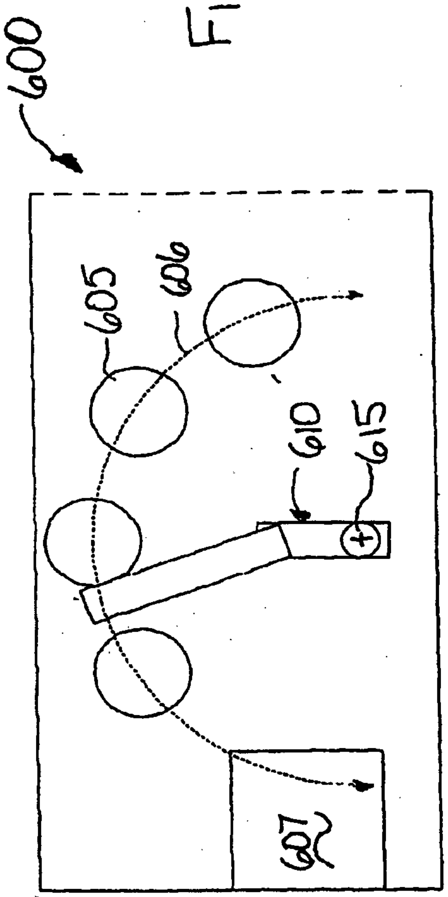


FIG. 11

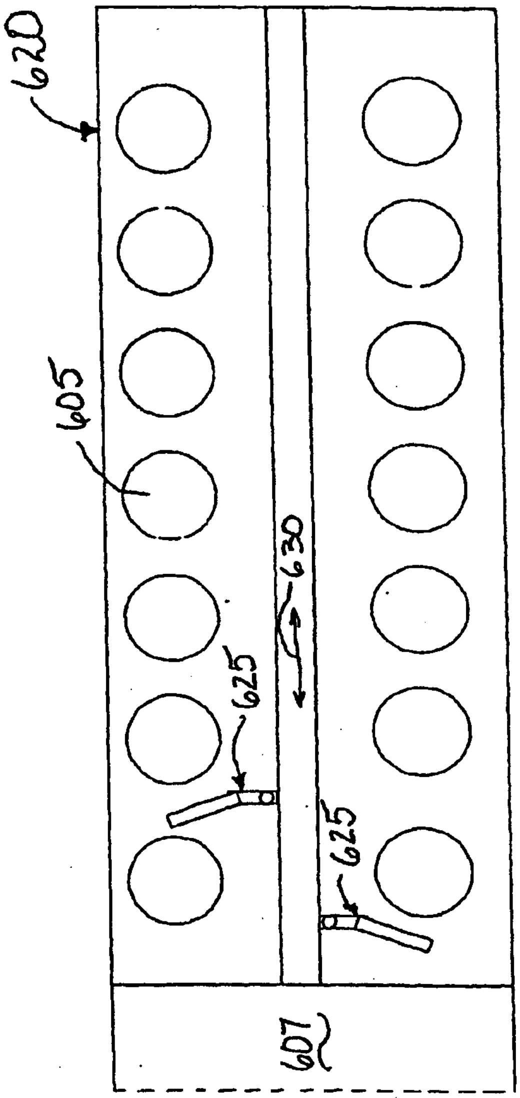
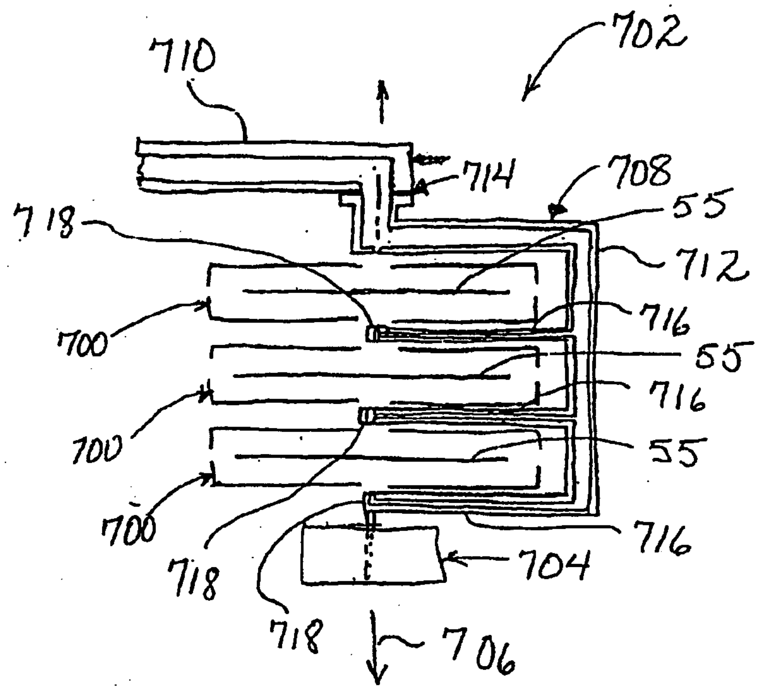


FIG. 12


702
710
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712
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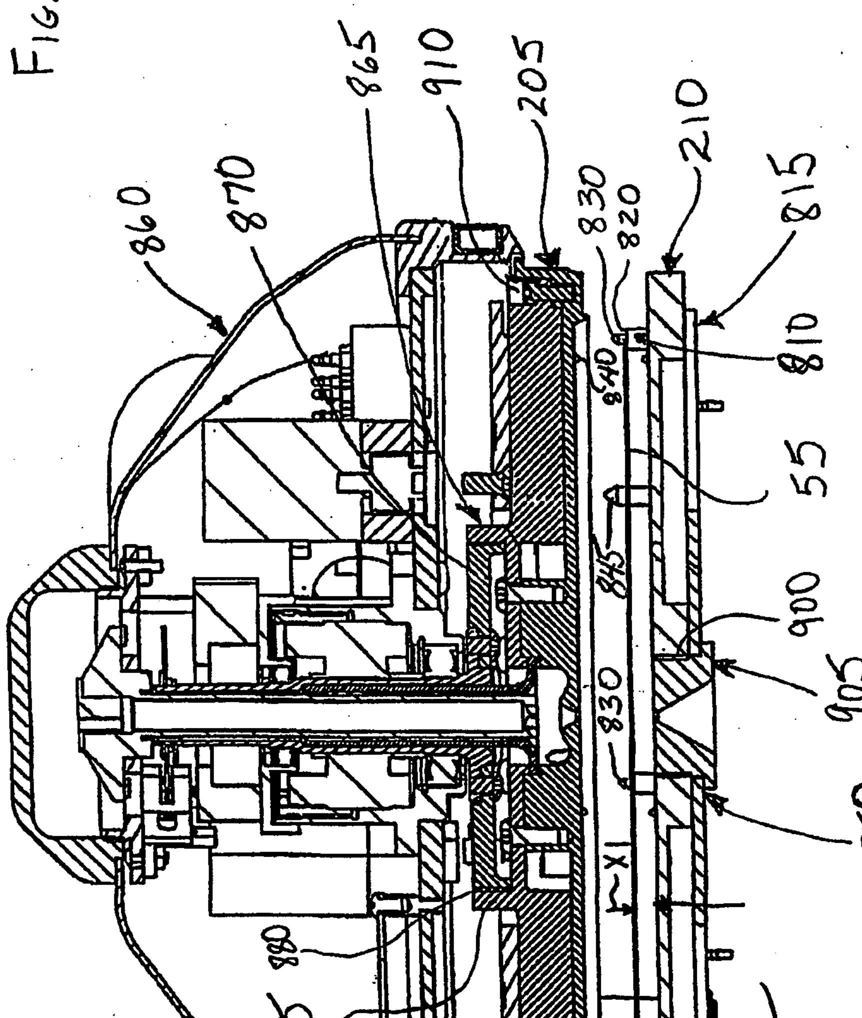
55
700
716
718
704
718
706

FIG. 13

FIG. 14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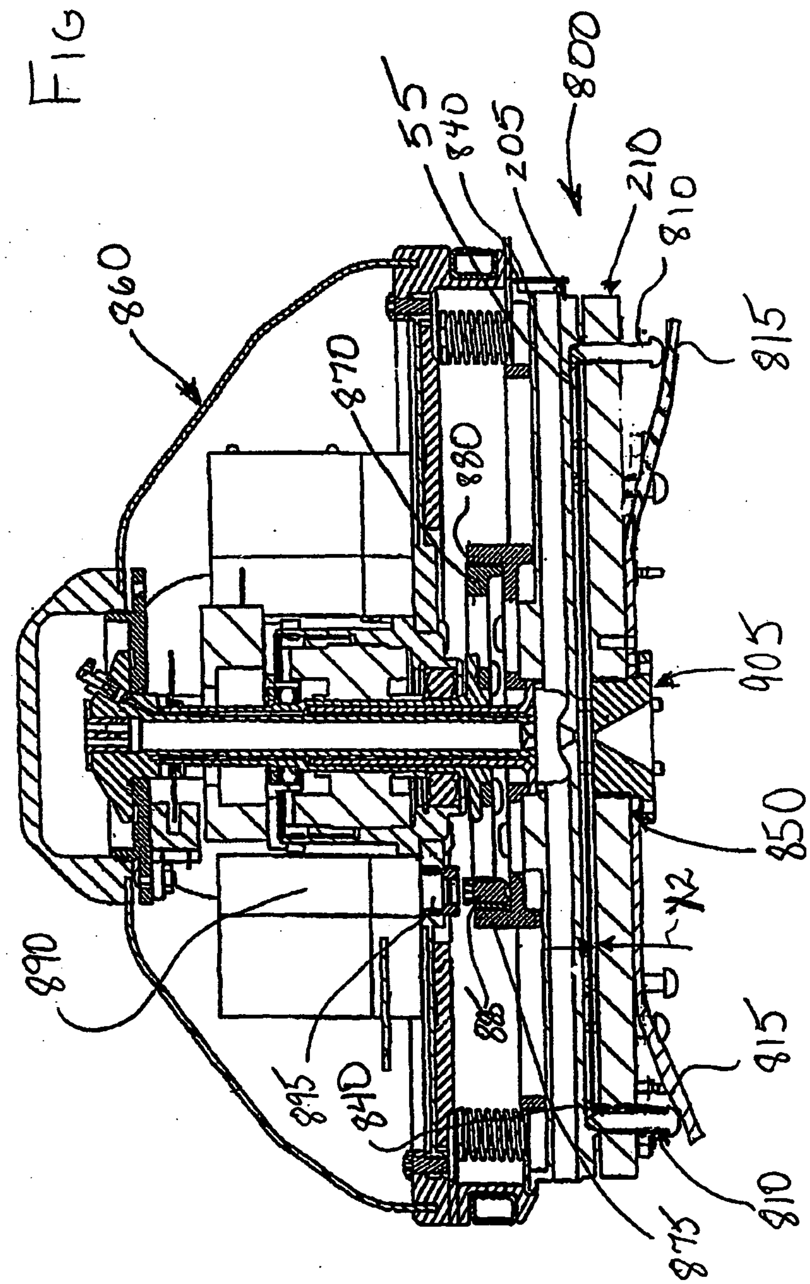
905
830
850
X1
880
875
845
800

FIG. 15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810

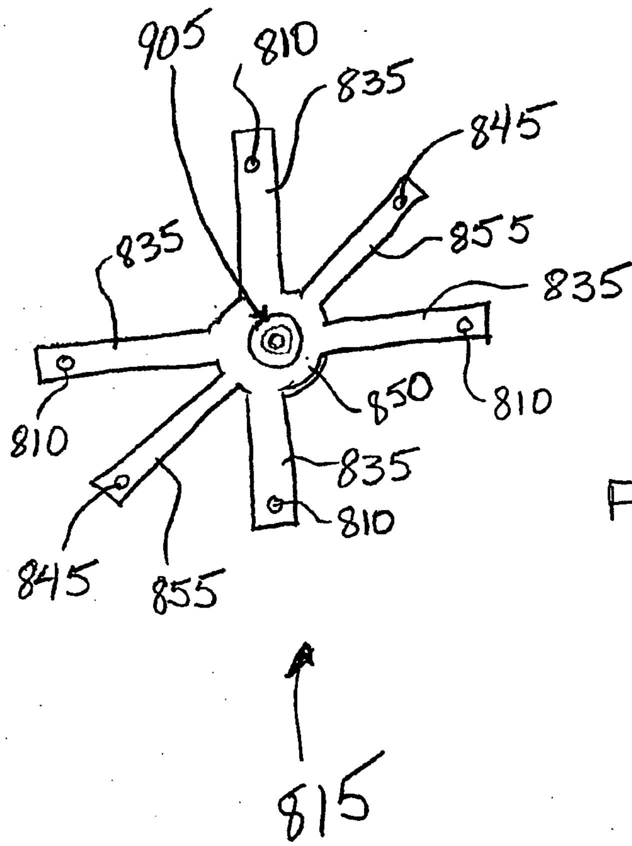
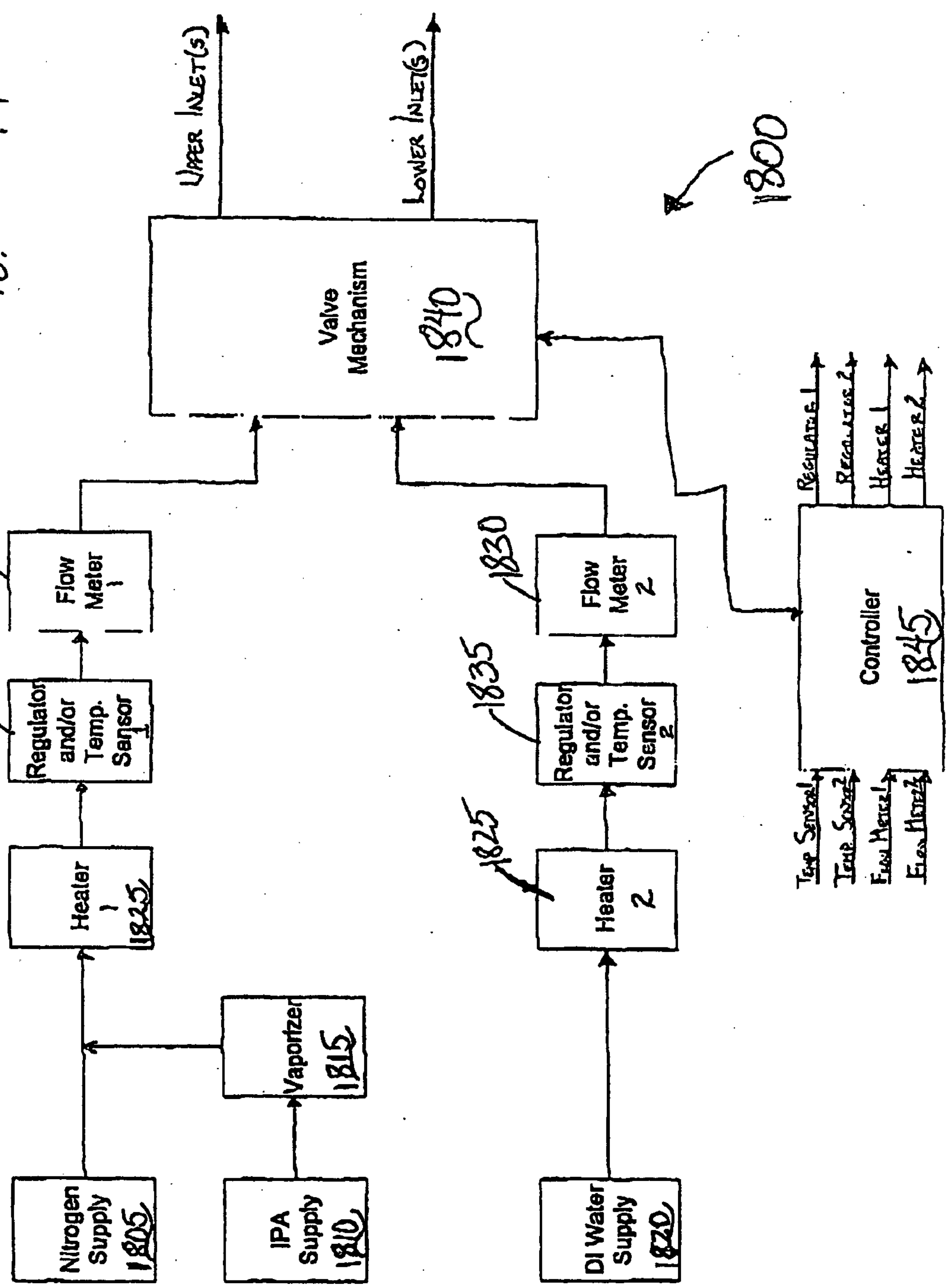


FIG. 16

FIG. 17



Upper Inlet(s)
Lower Inlet(s)
1800
Valve Mechanism
1840
Flow Meter 1
1830
Regulator and/or Temp. Sensor 1
1835
Heater 1
1825
Nitrogen Supply
1805
IPA Supply
1810
Vaporizer
1815
DI Water Supply
1820
Heater 2
1825
Regulator and/or Temp. Sensor 2
1835
Flow Meter 2
1830
Controller
1845
Regulator 1
Regulator 2
Heater 1
Heater 2
Temp Sensor 1
Temp Sensor 2
Flow Meter 1
Flow Meter 2

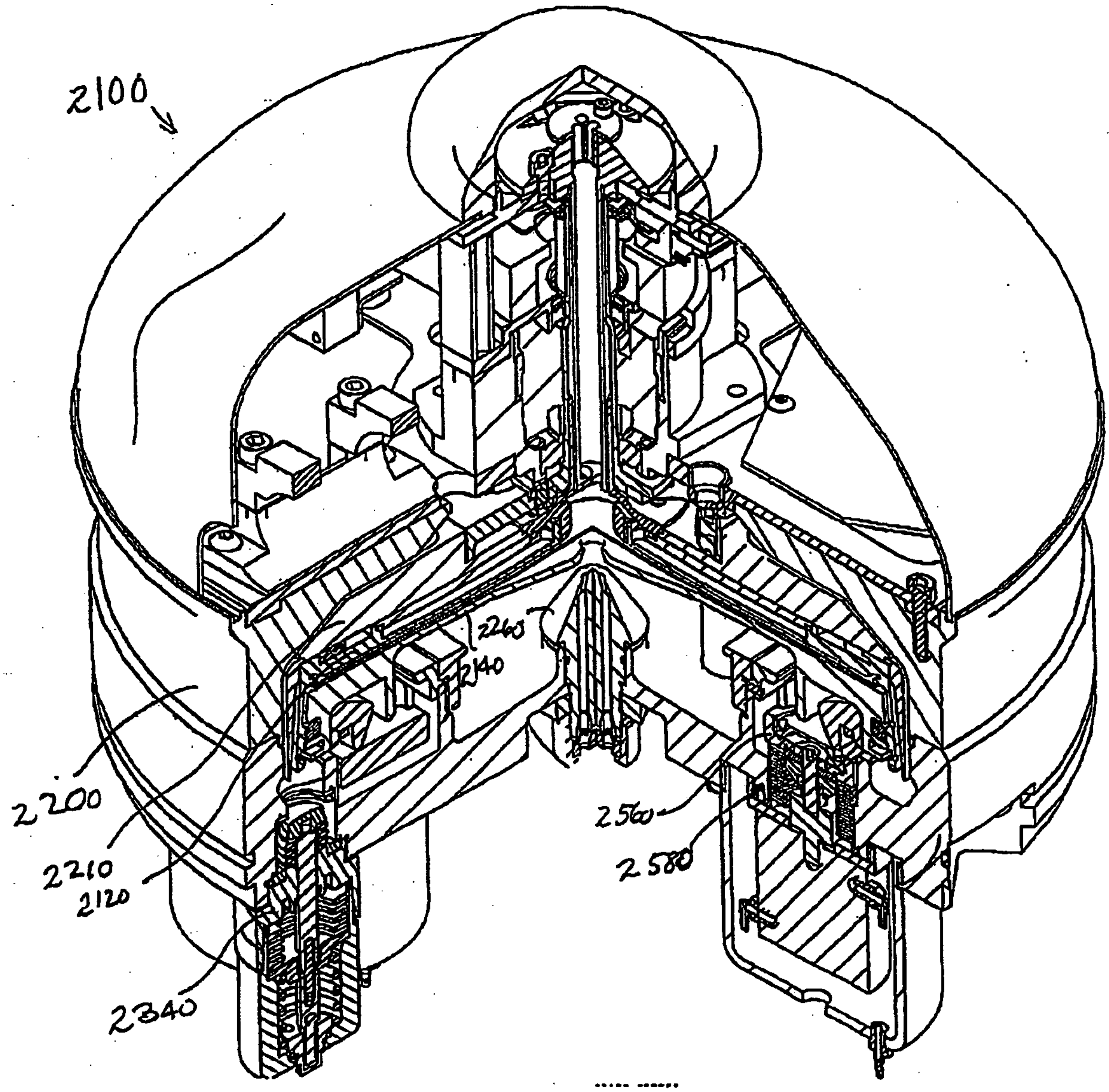
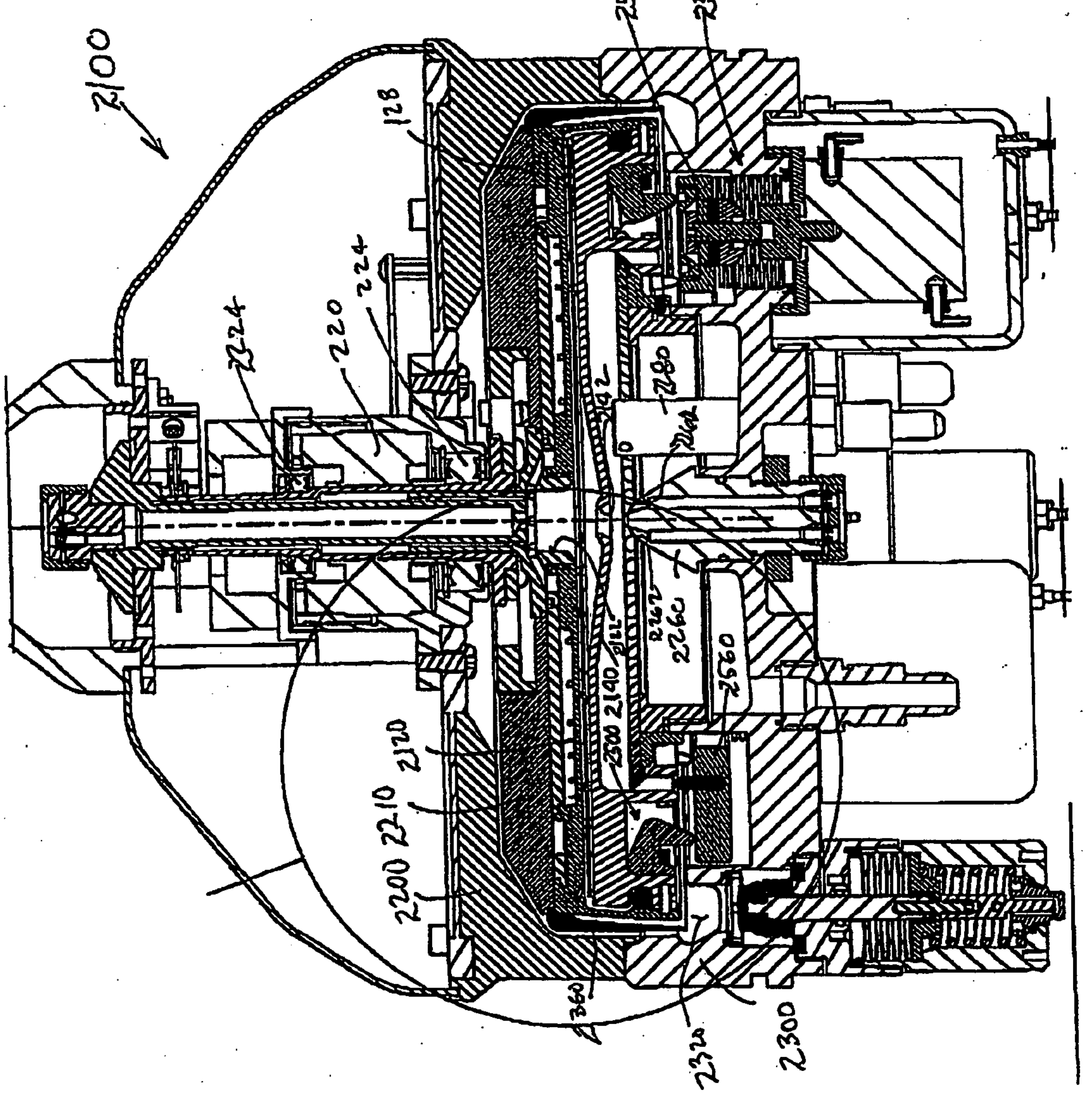


Fig. 18

Fig 19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224
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2300
2320
2360
2560

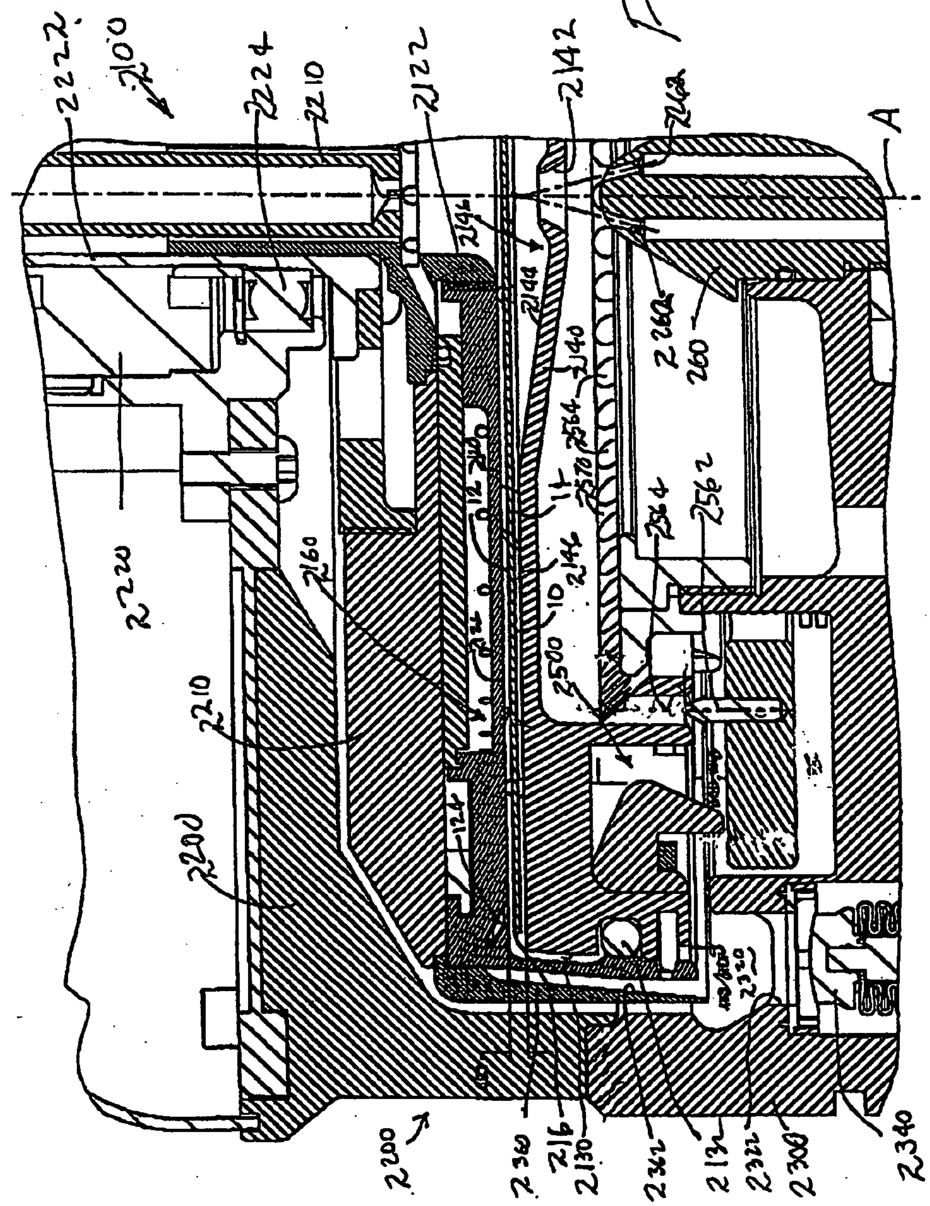


Fig 20

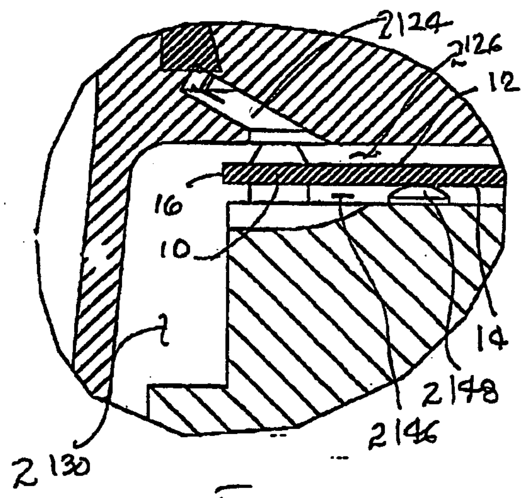
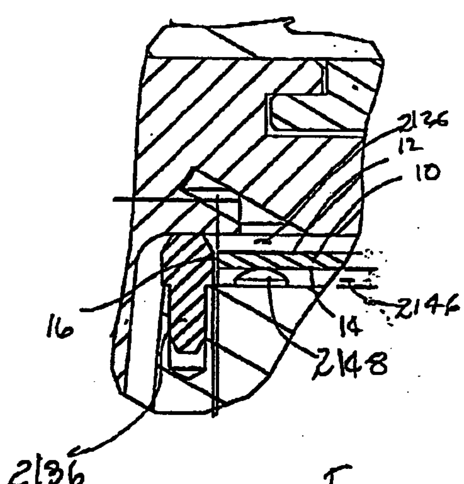

2124
2126
12
16
10
14
2148
2146
2130

Fig. 21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10
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14
2146
2148
2136

Fig. 22

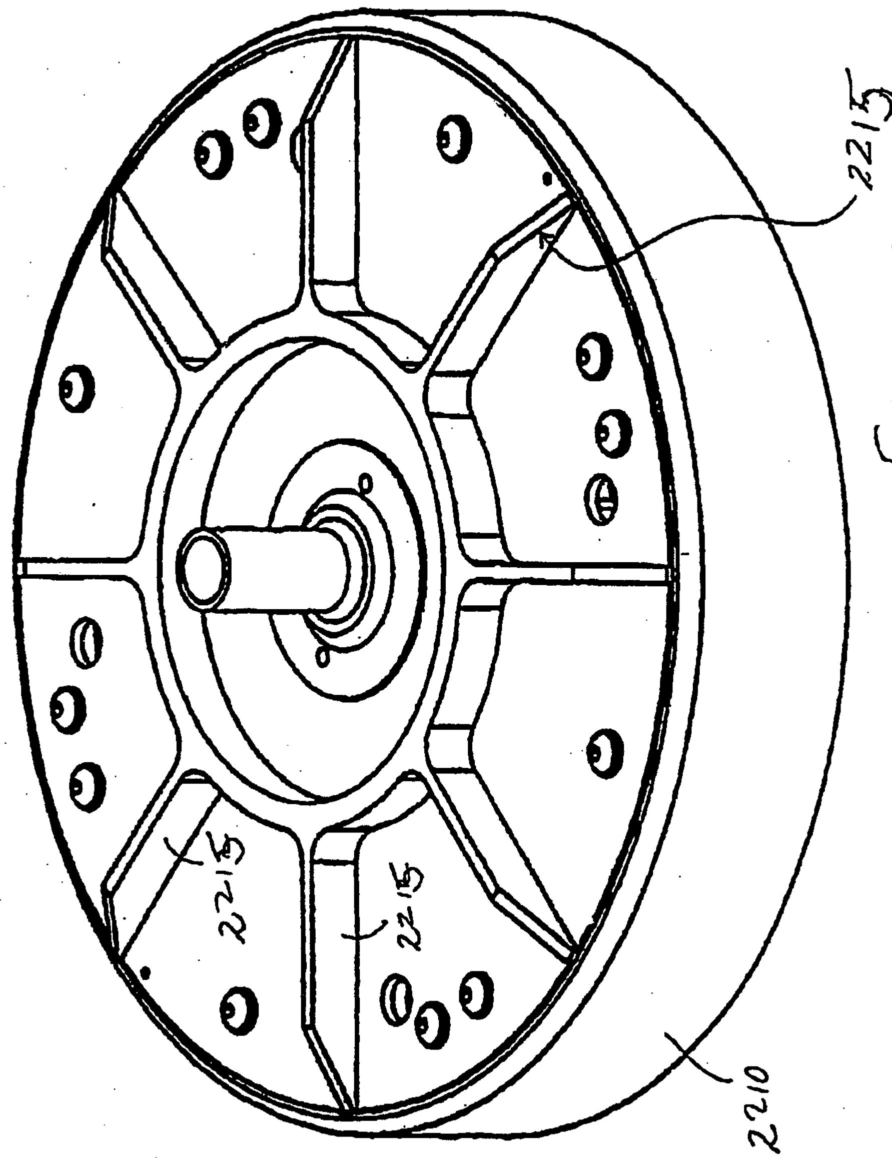
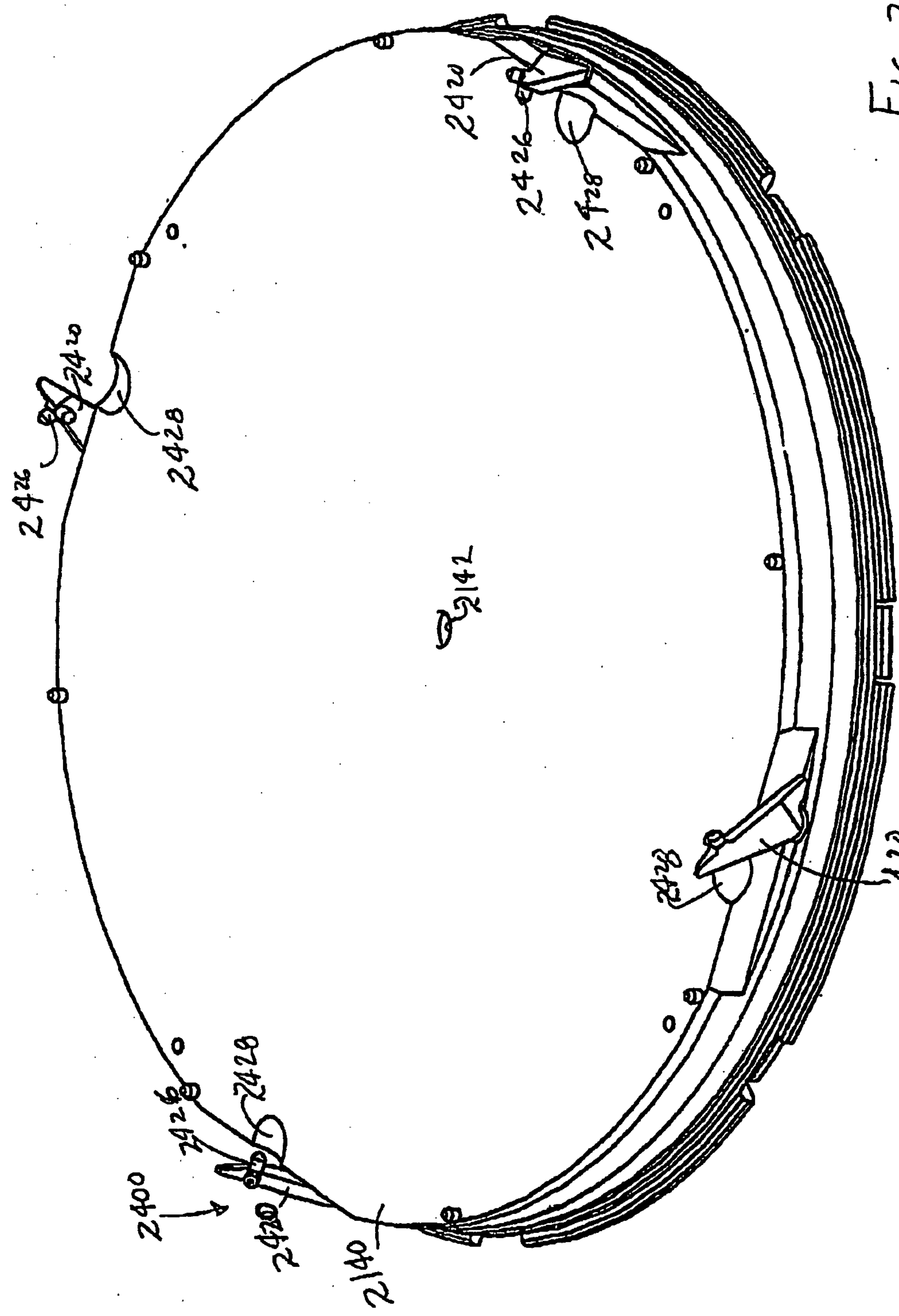


Fig 23


2420
2426
2428
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2428
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2142
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2428
2428
2426
2400
2420
2140

FIG. 24

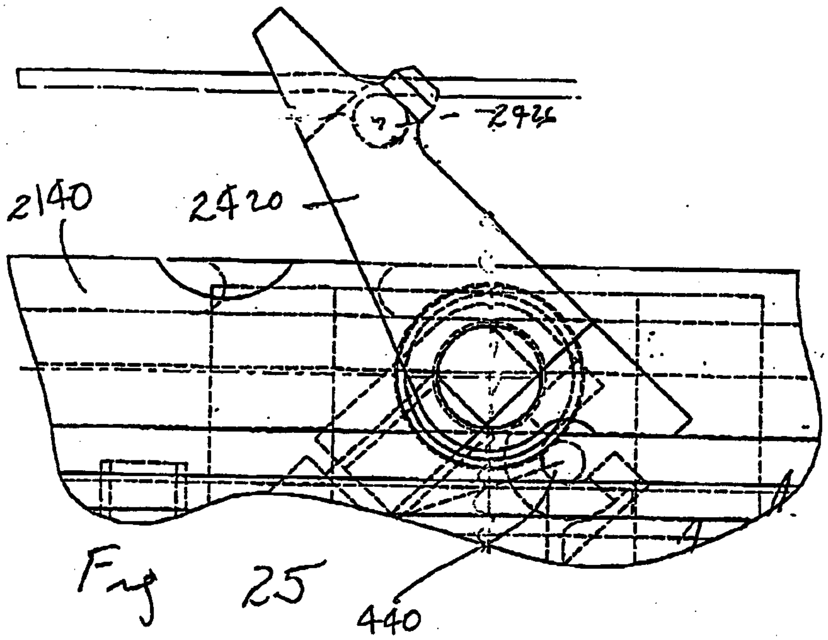

Fig 25

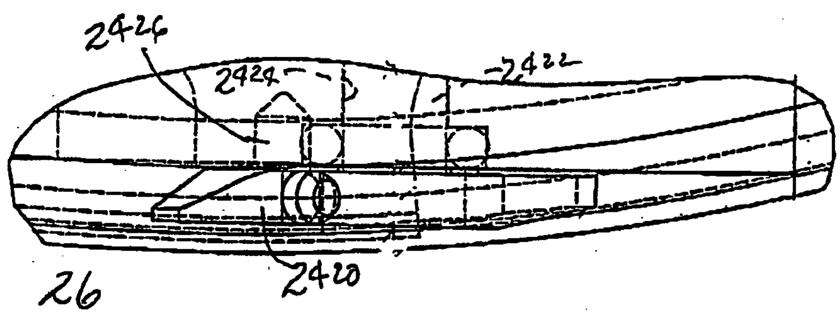

Fig 26